Frederic S. Lee.

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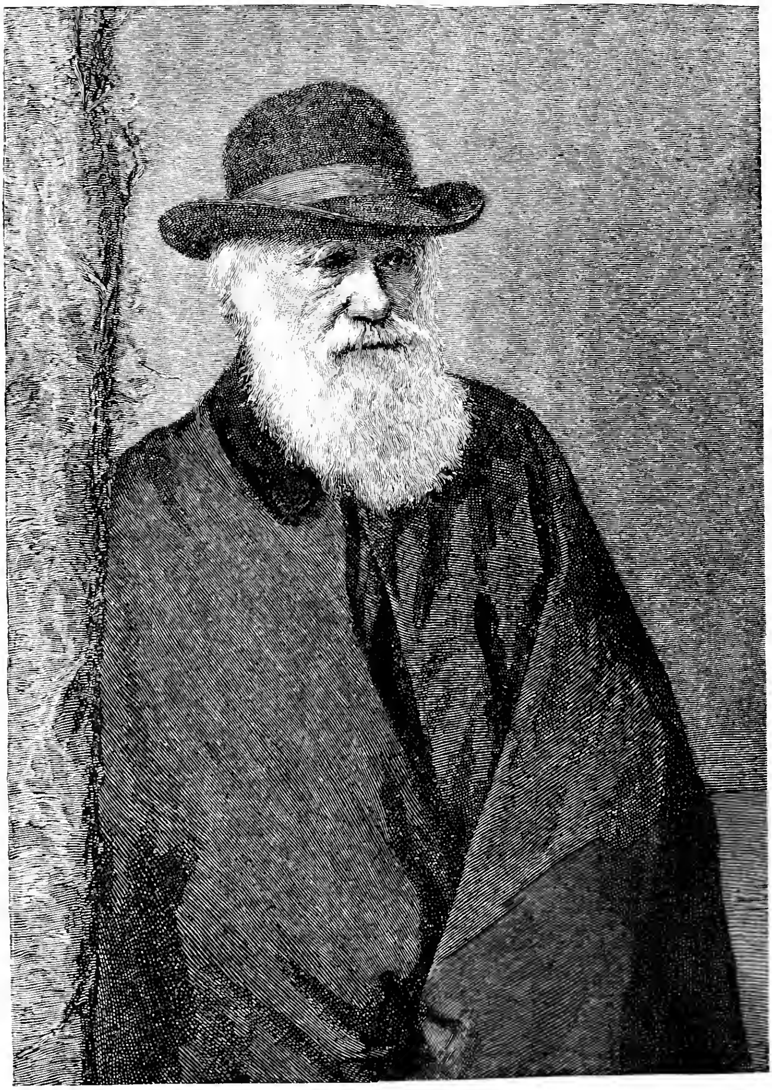

Ch. Darwin

THE POPULAR SCIENCE MONTHLY.

NOVEMBER, 1901.

ON THE TENDENCY OF SPECIES TO FORM VARIETIES; AND ON THE PERPETUATION OF VARIETIES AND SPECIES BY NATURAL MEANS OF SELECTION.*

BY CHARLES DARWIN, ESQ., F.R.S., F.L.S., AND F.G.S., AND ALFRED WALLACE, ESQ
COMMUNICATED BY SIR CHARLES LYELL, F.R.S., F.L.S., AND J. D. HOOKER, ESQ., M.D., V.P.R.S., F.R.S., ETC.

(Read July 1, 1858.)

LONDON, June 30th, 1858.

My Dear Sir:—The accompanying papers, which we have the honour of communicating to the Linnean Society, and which all relate to the same subject, viz., the Laws which affect the Production of Varieties, Races, and Species, contain the results of the investigations of two indefatigable naturalists, Mr. Charles Darwin and Mr. Alfred Wallace.

* From Vol. III. (1858) of the 'Journal' of the Linnean Society. The original announcement of the principle of the origin of species by natural selection made by Darwin and Wallace before the Linnean Society will be of great interest to readers of this journal. It is perhaps the most important event in the history of science, and the circumstances give to it a dramatic character. Sir Charles Lyell and Sir Joseph Hooker explain in their letter of transmission how it came to pass that the manuscripts were presented. In this connection, however, the following extract of a letter from Darwin to Lyell (June 25, 1858) may be reproduced:

There is nothing in Wallace's sketch which is not written out much fuller in my sketch, copied out in 1844, and read by Hooker some dozen years ago. About a year ago I sent a short sketch, of which I have a copy, of my views (owing to correspondence on several points) to Asa Gray, so that I could most truly say and prove that I take nothing from Wallace. I should be extremely glad now to publish a sketch of my general views in about a dozen pages or so; but I cannot persuade myself that I can do so honourably. Wallace says nothing about publication, and I enclose his letter. But as I had not intended to publish any sketch, can I do so honourably, because Wallace has sent me an outline of his doctrine? I would far rather burn my whole book, than that he

These gentlemen having, independently and unknown to one another, conceived the same very ingenious theory to account for the appearance and perpetuation of varieties and of specific forms on our planet, may both fairly claim the merit of being original thinkers in this important line of inquiry; but neither of them having published his views, though Mr. Darwin has for many years past been repeatedly urged by us to do so, and both authors having now unreservedly placed their papers in our hands, we think it would best promote the interests of science that a selection from them should be laid before the Linnean Society.

Taken in the order of their dates, they consist of:

1. Extracts from a MS. work on Species,* by Mr. Darwin, which was sketched in 1839, and copied in 1844, when the copy was read by Dr. Hooker, and its contents afterwards communicated to Sir Charles Lyell. The first Part is devoted to 'The Variation of Organic Beings under Domestication and in their Natural State'; and the second chapter of that Part, from which we propose to read to the Society the extracts referred to, is headed, 'On the Variation of Organic Beings in a state of Nature; on the Natural Means of Selection; on the Comparison of Domestic Races and true Species.'

2. An abstract of a private letter addressed to Professor Asa Gray, of Boston, U. S., in October, 1857, by Mr. Darwin, in which he repeats his views, and which shows that these remained unaltered from 1839 to 1857.

3. An Essay by Mr. Wallace, entitled 'On the Tendency of Varieties to depart indefinitely from the Original Type.' This was written at Ternate in February, 1858, for the perusal of his friend and correspondent Mr. Darwin, and sent to him with the expressed wish that it should be forwarded to Sir Charles Lyell, if Mr. Darwin thought it sufficiently novel and interesting. So highly did Mr. Darwin appreciate the value of the views therein set forth, that he proposed, in a letter to Sir Charles Lyell, to obtain Mr. Wallace's consent to allow the Essay to be published as soon as possible. Of this step we highly approved, provided Mr. Darwin did not withhold from the public, as

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or any other man should think that I had behaved in a paltry spirit. Do you not think his having sent me this sketch ties my hands? * * * If I could honourably publish, I would state that I was now induced to publish a sketch (and I should be very glad to be permitted to say, to follow your advice long ago given) from Wallace having sent me an outline of my general conclusions. We differ only, [in] that I was led to my views from what artificial selection has done for domestic animals. I would send Wallace a copy of my letter to Asa Gray, to show him that I had not stolen his doctrine. But I cannot tell whether to publish now would not be base and paltry. This was my first impression, and I should have certainly have acted on it had it not been for your letter.

* This MS. work was never intended for publication, and therefore was not written with care.—C. D., 1858.

he was strongly inclined to do (in favor of Mr. Wallace), the memoir which he had himself written on the same subject, and which, as before stated, one of us had perused in 1844, and the contents of which we had both of us been privy to for many years. On representing this to Mr. Darwin, he gave us permission to make what use we thought proper of his memoir, &c.; and in adopting our present course, of presenting it to the Linnean Society, we have explained to him that we are not solely considering the relative claims to priority of himself and his friend, but the interests of science generally; for we feel it to be desirable that views founded on a wide deduction from facts, and matured by years of reflection, should constitute at once a goal from which others may start, and that, while the scientific world is waiting for the appearance of Mr. Darwin's complete work, some of the leading results of his labours, as well as those of his able correspondent, should together be laid before the public.

We have honour to be yours very obediently,

CHARLES LYELL.
JOS. D. HOOKER.

J. J. BENNETT, Esq.,
Secretary of the Linnean Society.

1. *Extract from an unpublished Work on Species, by* C. DARWIN, Esq., *consisting of a portion of a Chapter entitled, 'On the Variation of Organic Beings in a state of Nature; on the Natural Means of Selection; on the Comparison of Domestic Races and true Species.'*

De Candolle, in an eloquent passage, has declared that all nature is at war, one organism with another, or with external nature. Seeing the contented face of nature, this may at first well be doubted; but reflection will inevitably prove it to be true. The war, however, is not constant, but recurrent in a slight degree at short periods, and more severely at occasional more distant periods; and hence its effects are easily overlooked. It is the doctrine of Malthus applied in most cases with tenfold force. As in every climate there are seasons, for each of its inhabitants, of greater and less abundance, so all annually breed; and the moral restraint which in some small degree checks the increase of mankind is entirely lost. Even slow-breeding mankind has doubled in twenty-five years; and if he could increase his food with greater ease, he would double in less time. But for animals without artificial means, the amount of food for each species must, *on an average*, be constant, whereas the increase of all organisms tends to be geometrical, and in a vast majority of cases at an enormous ratio. Suppose in a certain spot there are eight pairs of birds, and that *only* four pairs of them annually (including double hatches) rear only four young, and that these go on rearing their young at the same rate, then at the end

of seven years (a short life, excluding violent deaths, for any bird) there will be 2048 birds, instead of the original sixteen. As this increase is quite impossible, we must conclude either that birds do not rear nearly half their young, or that the average life of a bird is, from accident, not nearly seven years. Both checks probably concur. The same kind of calculation applied to all plants and animals affords results more or less striking, but in very few instances more striking than in man.

Many practical illustrations of this rapid tendency to increase are on record, among which, during peculiar seasons, are the extraordinary numbers of certain animals; for instance, during the years 1826 to 1828, in La Plata, when from drought some millions of cattle perished, the whole country actually *swarmed* with mice. Now I think it cannot be doubted that during the breeding-season all the mice (with the exception of a few males or females in excess) ordinarily pair, and therefore that this astounding increase during three years must be attributed to a greater number than usual surviving the first year, and then breeding, and so on till the third year, when their numbers were brought down to their usual limits on the return of wet weather. Where man has introduced plants and animals into a new and favourable country, there are many accounts in how surprisingly few years the whole country has become stocked with them. This increase would necessarily stop as soon as the country was fully stocked; and yet we have every reason to believe, from what is known of wild animals, that *all* would pair in the spring. In the majority of cases it is most difficult to imagine where the checks fall—though generally, no doubt, on the seeds, eggs, and young; but when we remember how impossible, even in mankind (so much better known than any other animal), it is to infer from repeated casual observations what the average duration of life is, or to discover the different percentage of deaths to births in different countries, we ought to feel no surprise at our being unable to discover where the check falls in any animal or plant. It should always be remembered, that in most cases the checks are recurrent yearly in a small, regular degree, and in an extreme degree during unusually cold, hot, dry, or wet years, according to the constitution of the being in question. Lighten any check in the least degree, and the geometrical powers of increase in every organism will almost instantly increase the average number of the favoured species. Nature may be compared to a surface on which rest ten thousand sharp wedges touching each other and driven inwards by incessant blows. Fully to realize these views much reflection is requisite. Malthus on man should be studied; and all such cases as those of the mice in La Plata, of the cattle and horses when first turned out in South America, of the birds by our calculation, etc., should be well considered. Reflect on the enormous multiplying

power *inherent and annually in action* in all animals; reflect on the countless seeds scattered by a hundred ingenious contrivances, year after year, over the whole face of the land; and yet we have every reason to suppose that the average percentage of each of the inhabitants of a country usually remains constant. Finally, let it be borne in mind that this average number of individuals (the external conditions remaining the same) in each country is kept up by recurrent struggles against other species or against external nature (as on the borders of the Arctic regions, where the cold checks life), and that ordinarily each individual of every species holds its place, either by its own struggle and capacity of acquiring nourishment in some period of its life, from the egg upwards; or by the struggle of its parents (in short-lived organisms, when the main check occurs at longer intervals) with other individuals of the *same* or *different* species.

But let the external conditions of a country alter. If in a small degree, the relative proportions of the inhabitants will in most cases simply be slightly changed; but let the number of inhabitants be small, as on an island, and free access to it from other countries be circumscribed, and let the change of conditions continue progressing (forming new stations), in such a case the original inhabitants must cease to be as perfectly adapted to the changed conditions as they were originally. It has been shown in a former part of this work, that such changes of external conditions would, from their acting on the reproductive system, probably cause the organization of those beings which were most affected to become, as under domestication, plastic. Now, can it be doubted, from the struggle each individual has to obtain subsistence, that any minute variation in structure, habits, or instincts, adapting that individual better to the new conditions, would tell upon its vigour and health? In the struggle it would have a better *chance* of surviving; and those of its offspring which inherited the variation, be it ever so slight, would also have a better *chance*. Yearly more are bred than can survive; the smallest grain in the balance, in the long run, must tell on which death shall fall, and which shall survive. Let this work of selection on the one hand, and death on the other, go on for a thousand generations, who will pretend to affirm that it would produce no effect, when we remember what, in a few years, Bakewell effected in cattle, and Western in sheep, by this identical principle of selection?

To give an imaginary example from changes in progress on an island:—let the organization of a canine animal which preyed chiefly on rabbits, but sometimes on hares, become slightly plastic; let these same changes cause the number of rabbits very slowly to decrease, and the number of hares to increase; the effect of this would be that the fox or dog would be driven to try to catch more hares; his organization, however, being slightly plastic, those individuals with the lightest forms,

longest limbs, and best eyesight, let the difference be ever so small, would be slightly favoured, and would tend to live longer, and to survive during that time of the year when food was scarcest; they would also rear more young, which would tend to inherit these slight peculiarities. The less fleet ones would be rigidly destroyed. I can see no more reason to doubt that these causes in a thousand generations would produce a marked effect, and adapt the form of the fox or dog to the catching of hares instead of rabbits, than that greyhounds can be improved by selection and careful breeding. So would it be with plants under similar circumstances. If the number of individuals of a species with plumed seeds could be increased by greater powers of dissemination within its own area (that is, if the check to increase fell chiefly on the seeds), those seeds which were provided with ever so little more down, would in the long run be most disseminated; hence a greater number of seeds thus formed would germinate, and would tend to produce plants inheriting the slightly better-adapted down.*

Besides this natural means of selection, by which those individuals are preserved, whether in their egg, or larval, or mature state, which are best adapted to the place they fill in nature, there is a second agency at work in most unisexual animals, tending to produce the same effect, namely, the struggle of the males for the females. These struggles are generally decided by the law of battle, but in the case of birds, apparently, by the charms of their song, by their beauty or their power of courtship, as in the dancing rock-thrush of Guiana. The most vigourous and healthy males, implying perfect adaptation, must generally gain the victory in their contests. This kind of selection, however, is less rigorous than the other; it does not require the death of the less successful, but gives to them fewer descendants. The struggle falls, moreover, at a time of the year when food is generally abundant, and perhaps the effect chiefly produced would be the modification of the secondary sexual characters, which are not related to the power of obtaining food, or to defence from enemies, but to fighting with or rivalling other males. The result of this struggle amongst the males may be compared in some respects to that produced by those agriculturists who pay less attention to the careful selection of all their young animals, and more to the occasional use of a choice mate.

2. *Abstract of a Letter from* C. Darwin, *Esq., to Professor* Asa Gray, *Boston, U. S., dated Down, September 5th,* 1857.

1. It is wonderful what the principle of selection by man, that is the picking out of individuals with any desired quality, and breeding from them, and again picking out, can do. Even breeders have been astounded at their own results. They can act on differences inappre-

* I can see no more difficulty in this, than in the planter improving his varieties of the cotton plant.—C. D., 1858.

ciable to an uneducated eye. Selection has been *methodically* followed in *Europe* for only the last half century; but it was occasionally, and even in some degree methodically, followed in the most ancient times. There must have been also a kind of unconscious selection from a remote period, namely in the preservation of the individual animals (without any thought of their offspring) most useful to each race of man in his particular circumstances. The 'roguing,' as nurserymen call the destroying of varieties which depart from their type, is a kind of selection. I am convinced that intentional and occasional selection has been the main agent in the production of our domestic races; but however this may be, its great power of modification has been indisputably shown in later times. Selection acts only by the accumulation of slight or greater variations, caused by external conditions, or by the mere fact that in generation the child is not absolutely similar to its parent. Man, by this power of accumulating variations, adapts living beings to his wants—may be said to make the wool of one sheep good for carpets, of another for cloth, etc.

2. Now suppose there were a being who did not judge by mere external appearances, but who could study the whole internal organization, who was never capricious, and should go on selecting for one object during millions of generations; who will say what he might not effect? In nature we have some *slight* variations occasionally in all parts; and I think it can be shown that changed conditions of existence is the main cause of the child not exactly resembling its parents; and in nature geology shows us what changes have taken place and are taking place. We have almost unlimited time; no one but a practical geologist can fully appreciate this. Think of the Glacial period, during the whole of which the same species at least of shells have existed; there must have been during this period millions on millions of generations.

3. I think it can be shown that there is such an unerring power at work in *Natural Selection* (the title of my book), which selects exclusively for the good of each organic being. The elder De Candolle, W. Herbert, and Lyell have written excellently on the struggle for life; but even they have not written strongly enough. Reflect that every being (even the elephant) breeds at such a rate, that in a few years, or at most a few centuries, the surface of the earth would not hold the progeny of one pair. I have found it hard constantly to bear in mind that the increase of every single species is checked during some part of its life, or during some shortly recurrent generation. Only a few of those annually born can live to propagate their kind. What a trifling difference must often determine which shall survive, and which perish!

4. Now take the case of a country undergoing some change. This will tend to cause some of its inhabitants to vary slightly—not but that I believe most beings vary at all times enough for selection to act on

them. Some of its inhabitants will be exterminated; and the remainder will be exposed to the mutual action of a different set of inhabitants, which I believe to be far more important to the life of each being than mere climate. Considering the infinitely various methods which living beings follow to obtain food by struggling with other organisms, to escape danger at various times of life, to have their eggs or seeds disseminated, etc., etc., I cannot doubt that during millions of generations individuals of a species will be occasionally born with some slight variation, profitable to some part of their economy. Such individuals will have a better chance of surviving, and of propagating their new and slightly different structure; and the modification may be slowly increased by the accumulative action of natural selection to any profitable extent. The variety thus formed will either coexist with, or, more commonly, will exterminate its parent form. An organic being, like the woodpecker or misseltoe, may thus come to be adapted to a score of contingencies—natural selection accumulating those slight variations in all parts of its structure, which are in any way useful to it during any part of its life.

5. Multiform difficulties will occur to every one, with respect to this theory. Many can, I think, be satisfactorily answered. *Natura non facit saltum* answers some of the most obvious. The slowness of the change, and only a few individuals undergoing change at one time, answers others. The extreme imperfection of our geological records answers others.

6. Another principle, which may be called the principle of divergence, plays, I believe, an important part in the origin of species. The same spot will support more life if occupied by very diverse forms. We see this in the many generic forms in a square yard of turf, and in the plants or insects on any little uniform islet, belonging almost invariably to as many genera and families as species. We can understand the meaning of this fact amongst the higher animals, whose habits we understand. We know that it has been experimentally shown that a plot of land will yield a greater weight if sown with several species and genera of grasses, than if sown with only two or three species. Now, every organic being, by propagating so rapidly, may be said to be striving its utmost to increase in numbers. So it will be with the offspring of any species after it has become diversified into varieties, or sub-species, or true species. And it follows, I think, from the foregoing facts, that the varying offspring of each species will try (only few will succeed) to seize on as many and as diverse places in the economy of nature as possible. Each new variety or species, when formed, will generally take the place of, and thus exterminate its less well-fitted parent. This I believe to be the origin of the classification and affinities of organic beings at all times; for organic beings always

seem to branch and sub-branch like the limbs of a tree from a common trunk, the flourishing and diverging twigs destroying the less vigorous —the dead and lost branches rudely representing extinct genera and families.

This sketch is *most* imperfect; but in so short a space I cannot make it better. Your imagination must fill up very wide blanks.

C. DARWIN.

3. *On the Tendency of Varieties to depart indefinitely from the Original Type. By* ALFRED RUSSEL WALLACE.

One of the strongest arguments which have been adduced to prove the original and permanent distinctness of species is, that *varieties* produced in a state of domesticity are more or less unstable, and often have a tendency, if left to themselves, to return to the normal form of the parent species; and this instability is considered to be a distinctive peculiarity of all varieties, even of those occurring among wild animals in a state of nature, and to constitute a provision for preserving unchanged the originally created distinct species.

In the absence or scarcity of facts and observations as to *varieties* occurring among wild animals, this argument has had great weight with naturalists, and has led to a very general and somewhat prejudiced belief in the stability of species. Equally general, however, is the belief in what are called 'permanent or true varieties,'—races of animals which continually propagate their like, but which differ so slightly (although constantly) from some other race, that the one is considered to be a *variety* of the other. Which is the *variety* and which the original *species,* there is generally no means of determining, except in those rare cases in which the one race has been known to produce an offspring unlike itself and resembling the other. This, however, would seem quite incompatible with the 'permanent invariability of species,' but the difficulty is overcome by assuming that such varieties have strict limits, and can never again vary further from the original type, although they may return to it, which, from the analogy of the domesticated animals, is considered to be highly probable, if not certainly proved.

It will be observed that this argument rests entirely on the assumption, that *varieties* occurring in a state of nature are in all respects analogous to or even identical with those of domestic animals, and are governed by the same laws as regards their permanence or further variation. But it is the object of the present paper to show that this assumption is altogether false, that there is a general principle in nature which will cause many *varieties* to survive the parent species, and to give rise to successive variations departing further and further from the original type, and which also produces, in domesticated animals, the tendency of varieties to return to the parent form.

The life of wild animals is a struggle for existence. The full exertion of all their faculties and all their energies is required to preserve their own existence and provide for that of their infant offspring. The possibility of procuring food during the least favourable seasons, and of escaping the attacks of their most dangerous enemies, are the primary conditions which determine the existence both of individuals and of entire species. These conditions will also determine the population of a species; and by a careful consideration of all the circumstances we may be enabled to comprehend, and in some degree to explain, what at first sight appears so inexplicable—the excessive abundance of some species, while others closely allied to them are very rare.

The general proportion that must obtain between certain groups of animals is readily seen. Large animals cannot be so abundant as small ones; the carnivora must be less numerous than the herbivora; eagles and lions can never be so plentiful as pigeons and antelopes; the wild asses of the Tartarian deserts cannot equal in numbers the horses of the more luxuriant prairies and pampas of America. The greater or less fecundity of an animal is often considered to be one of the chief causes of its abundance or scarcity; but a consideration of the facts will show us that it really has little or nothing to do with the matter. Even the least prolific of animals would increase rapidly if unchecked, whereas it is evident that the animal population of the globe must be stationary, or perhaps, through the influence of man, decreasing. Fluctuations there may be; but permanent increase, except in restricted localities, is almost impossible. For example, our own observation must convince us that birds do not go on increasing every year in a geometrical ratio, as they would do, were there not some powerful check to their natural increase. Very few birds produce less than two young ones each year, while many have six, eight, or ten; four will certainly be below the average; and if we suppose that each pair produce young only four times in their life, that will also be below the average, supposing them not to die either by violence or want of food. Yet at this ratio how tremendous would be the increase in a few years from a single pair! A simple calculation will show that in fifteen years each pair of birds would have increased to nearly ten millions! whereas we have no reason to believe that the number of the birds of any country increases at all in fifteen or in one hundred and fifty years. With such powers of increase the population must have reached its limits, and have become stationary, in a very few years after the origin of each species. It is evident, therefore, that each year an immense number of birds must perish—as many in fact as are born; and as on the lowest calculation the progeny are each year twice as numerous as their parents, it follows that, whatever be the average number of individuals existing in any given country, *twice that number*

must perish annually,—a striking result, but one which seems at least highly probable, and is perhaps under rather than over the truth. It would therefore appear that, as far as the continuance of the species and the keeping up the average number of individuals are concerned, large broods are superfluous. On the average all above *one* become food for hawks and kites, wild cats and weasels, or perish of cold and hunger as winter comes on. This is strikingly proved by the case of particular species; for we find that their abundance in individuals bears no relation whatever to their fertility in producing offspring. Perhaps the most remarkable instance of an immense bird population is that of the passenger pigeon of the United States, which lays only one, or at most two eggs, and is said to rear generally but one young one. Why is this bird so extraordinarily abundant, while others producing two or three times as many young are much less plentiful? The explanation is not difficult. The food most congenial to this species, and on which it thrives best, is abundantly distributed over a very extensive region, offering such differences of soil and climate, that in one part or another of the area the supply never fails. The bird is capable of a very rapid and long-continued flight, so that it can pass without fatigue over the whole of the district it inhabits, and as soon as the supply of food begins to fail in one place, is able to discover a fresh feeding-ground. This example strikingly shows us that the procuring a constant supply of wholesome food is almost the sole condition requisite for ensuring the rapid increase of a given species, since neither the limited fecundity, nor the unrestrained attacks of birds of prey and of man are here sufficient to check it. In no other birds are these peculiar circumstances so strikingly combined. Either their food is more liable to failure, or they have not sufficient power of wing to search for it over an extensive area, or during some season of the year it becomes very scarce, and less wholesome substitutes have to be found; and thus, though more fertile in offspring, they can never increase beyond the supply of food in the least favourable seasons. Many birds can only exist by migrating, when their food becomes scarce, to regions possessing a milder, or at least a different climate, though, as these migrating birds are seldom excessively abundant, it is evident that the countries they visit are still deficient in a constant and abundant supply of wholesome food. Those whose organization does not permit them to migrate when their food becomes periodically scarce, can never attain a large population. This is probably the reason why woodpeckers are scarce with us, while in the tropics they are among the most abundant of solitary birds. Thus the house sparrow is more abundant than the red-breast, because its food is more constant and plentiful,—seeds of grasses being preserved during the winter, and our farm-yards and stubble-fields furnishing an almost inexhaustible sup-

ply. Why, as a general rule, are aquatic, and especially sea birds, very numerous in individuals? Not because they are more prolific than others, generally the contrary; but because their food never fails, the sea-shores and river-banks daily swarming with a fresh supply of small mollusca and crustacea. Exactly the same laws will apply to mammals. Wild cats are prolific and have few enemies; why then are they never as abundant as rabbits? The only intelligible answer is, that their supply of food is more precarious. It appears evident, therefore, that so long as a country remains physically unchanged, the numbers of its animal population cannot materially increase. If one species does so, some others requiring the same kind of food must diminish in proportion. The numbers that die annually must be immense; and as the individual existence of each animal depends upon itself, those that die must be the weakest—the very young, the aged, and the diseased,—while those that prolong their existence can only be the most perfect in health and vigor—those who are best able to obtain food regularly, and avoid their numerous enemies. It is, as we commenced by remarking, 'a struggle for existence,' in which the weakest and least perfectly organized must always succumb.

Now it is clear that what takes place among the individuals of a species must also occur among the several allied species of a group,—viz., that those which are best adapted to obtain a regular supply of food, and to defend themselves against the attacks of their enemies and the vicissitudes of the seasons, must necessarily obtain and preserve a superiority in population; while those species which from some defect of power or organization are the least capable of counteracting the vicissitudes of food supply, etc., must diminish in numbers, and, in extreme cases, become altogether extinct. Between these extremes the species will present various degrees of capacity for ensuring the means of preserving life; and it is thus we account for the abundance or rarity of species. Our ignorance will generally prevent us from accurately tracing the effects to their causes; but could we become perfectly acquainted with the organization and habits of the various species of animals, and could we measure the capacity of each for performing the different acts necessary to its safety and existence under all the varying circumstances by which it is surrounded, we might be able even to calculate the proportionate abundance of individuals which is the necessary result.

If now we have succeeded in establishing these two points—1st, *that the animal population of a country is generally stationary, being kept down by a periodical deficiency of food, and other checks;* and, 2d, *that the comparative abundance or scarcity of the individuals of the several species is entirely due to their organization and resulting habits, which, rendering it more difficult to procure a regular supply of*

food and to provide for their personal safety in some cases than in others, can only be balanced by a difference in the population which have to exist in a given area—we shall be in a condition to proceed to the consideration of *varieties,* to which the preceding remarks have a direct and very important application.

Most or perhaps all the variations from the typical form of a species must have some definite effect, however slight, on the habits or capacities of the individuals. Even a change of colour might, by rendering them more or less distinguishable, affect their safety; a greater or less development of hair might modify their habits. More important changes, such as an increase in power or dimensions of the limbs or any of the external organs, would more or less affect their mode of procuring food, or the range of country which they inhabit. It is also evident that most changes would affect, either favourably or adversely, the powers of prolonging existence. An antelope with shorter or weaker legs must necessarily suffer more from the attacks of the feline carnivora; the passenger pigeon with less powerful wings would sooner or later be affected in its powers of procuring a regular supply of food; and in both cases the result must necessarily be a diminution of the population of the modified species. If, on the other hand, any species should produce a variety having slightly increased powers of preserving existence, that variety must inevitably in time acquire a superiority in numbers. These results must follow as surely as old age, intemperance, or scarcity of food produce an increased mortality. In both cases there may be many individual exceptions; but on the average the rule will invariably be found to hold good. All varieties will therefore fall into two classes—those which under the same conditions would never reach the population of the parent species, and those which would in time obtain and keep a numerical superiority. Now, let some alteration of physical conditions occur in the district—a long period of drought, a destruction of vegetation by locusts, the irruption of some new carnivorous animal seeking 'pastures new'—any change in fact tending to render existence more difficult to the species in question, and tasking its utmost powers to avoid complete extermination; it is evident that, of all the individuals composing the species, those forming the least numerous and most feebly organized variety would suffer first, and, were the pressure severe, must soon become extinct. The same causes continuing in action, the parent species would next suffer, would gradually diminish in numbers, and with a recurrence of similar unfavourable conditions might also become extinct. The superior variety would then alone remain, and on a return to favourable circumstances would rapidly increase in numbers and occupy the place of the extinct species and variety.

The *variety* would now have replaced the *species,* of which it would be a more perfectly developed and more highly organized form. It would be in all respects better adapted to secure its safety, and to prolong its individual existence and that of the race. Such a variety *could not* return to the original form; for that form is an inferior one, and could never compete with it for existence. Granted, therefore, a 'tendency' to reproduce the original type of the species, still the variety must ever remain preponderant in numbers, and under adverse physical conditions *again alone survive.* But this new, improved, and populous race might itself, in course of time, give rise to new varieties, exhibiting several diverging modifications of form, any of which, tending to increase the facilities for preserving existence, must, by the same general law, in their turn become predominant. Here, then, we have *progression and continued divergence* deduced from the general laws which regulate the existence of animals in a state of nature, and from the undisputed fact that varieties do frequently occur. It is not, however, contended that this result would be invariable; a change of physical conditions in the district might at times materially modify it, rendering the race which had been the most capable of supporting existence under the former conditions now the least so, and even causing the extinction of the newer, and, for a time, superior race, while the old or parent species and its first inferior varieties continued to flourish. Variations in unimportant parts might also occur, having no perceptible effect on the life-preserving powers; and the varieties so furnished might run a course parallel with the parent species, either giving rise to further variations or returning to the former type. All we argue for is, that certain varieties have a tendency to maintain their existence longer than the original species, and this tendency must make itself felt; for though the doctrine of chances or averages can never be trusted to on a limited scale, yet, if applied to high numbers, the results come nearer to what theory demands, and, as we approach to an infinity of examples, become strictly accurate. Now the scale on which nature works is so vast—the numbers of individuals and periods of time with which she deals approach so near to infinity, that any cause, however slight, and however liable to be veiled and counteracted by accidental circumstances, must in the end produce its full legitimate results.

Let us now turn to domesticated animals, and inquire how varieties produced among them are affected by the principles here enunciated. The essential difference in the condition of wild and domestic animals is this,—that among the former, their well-being and very existence depends upon the full exercise and healthy condition of all their senses and physical powers, whereas, among the latter, these are only partially exercised, and in some cases are absolutely unused. A wild animal has to search, and often to labour, for every mouthful of food—to ex-

ercise sight, hearing, and smell in seeking it, and in avoiding dangers, in procuring shelter from the inclemency of the seasons, and in providing for the subsistence and safety of its offspring. There is no muscle of its body that is not called into daily and hourly activity; there is no sense or faculty that is not strengthened by continual exercise. The domestic animal, on the other hand, has food provided for it, is sheltered and often confined, to guard it against the vicissitudes of the seasons, is carefully secured from the attacks of its natural enemies, and seldom even rears its young without human assistance. Half of its senses and faculties are quite useless; and the other half are but occasionally called into feeble exercise, while even its muscular system is only irregularly called into action.

Now when a variety of such an animal occurs, having increased power or capacity in any organ or sense, such increase is totally useless, is never called into action, and may even exist without the animal ever becoming aware of it. In the wild animal, on the contrary, all its faculties and powers being brought into full action for the necessities of existence, any increase becomes immediately available, is strengthened by exercise, and must even slightly modify the food, the habits, and the whole economy of the race. It creates as it were a new animal, one of superior powers, and which will necessarily increase in numbers and outlive those inferior to it.

Again, in the domesticated animal all variations have an equal chance of continuance; and those which would decidedly render a wild animal unable to compete with its fellows and continue its existence are no disadvantage whatever in a state of domesticity. Our quickly fattening pigs, short-legged sheep, pouter pigeons, and poodle dogs could never have come into existence in a state of nature, because the very first step towards such inferior forms would have led to the rapid extinction of the race; still less could they now exist in competition with their wild allies. The great speed but slight endurance of the race horse, the unwieldy strength of the ploughman's team, would both be useless in a state of nature. If turned wild on the pampas, such animals would probably soon become extinct, or under favourable circumstances might each lose those extreme qualities which would never be called into action, and in a few generations would revert to a common type, which must be that in which the various powers and faculties are so proportioned to each other as to be best adapted to procure food and secure safety,—that in which by the full exercise of every part of his organization the animal can alone continue to live. Domestic varieties, when turned wild, *must* return to something near the type of the original wild stock, *or become altogether extinct.*

We see, then, that no inferences as to varieties in a state of nature can be deduced from the observation of those occurring among domestic

animals. The two are so much opposed to each other in every circumstance of their existence, that what applies to the one is almost sure not to apply to the other. Domestic animals are abnormal, irregular, artificial; they are subject to varieties which never occur and never can occur in a state of nature: their very existence depends altogether on human care; so far are many of them removed from that just proportion of faculties, that true balance of organization, by means of which alone an animal left to its own resources can preserve its existence and continue its race.

The hypothesis of Lamarck—that progressive changes in species have been produced by the attempts of animals to increase the development of their own organs, and thus modify their structure and habits—has been repeatedly and easily refuted by all writers on the subject of varieties and species, and it seems to have been considered that when this was done the whole question has been finally settled; but the view here developed renders such an hypothesis quite unnecessary, by showing that similar results must be produced by the action of principles constantly at work in nature. The powerful retractile talons of the falcon- and the cat-tribes have not been produced or increased by the volition of those animals; but among the different varieties which occurred in the earlier and less highly organized form of these groups, *those always survived longest which had the greatest facilities for seizing their prey.* Neither did the giraffe acquire its long neck by desiring to reach the foliage of the more lofty shrubs, and constantly stretching its neck for the purpose, but because any varieties which occurred among its anti-types with a longer neck than usual *at once secured a fresh range of pasture over the same ground as their shorter-necked companions, and on the first scarcity of food were thereby enabled to outlive them.* Even the peculiar colours of many animals, especially insects, so closely resembling the soil or the leaves or the trunks on which they habitually reside, are explained on the same principle; for though in the course of ages varieties of many tints may have occurred, *yet those races having colours best adapted to concealment from their enemies would inevitably survive the longest.* We have also here an acting cause to account for that balance so often observed in nature,—a deficiency in one set of organs always being compensated by an increased development of some others—powerful wings accompanying weak feet, or great velocity making up for the absence of defensive weapons; for it has been shown that all varieties in which an unbalanced deficiency occurred could not long continue their existence. The action of this principle is exactly like that of the centrifugal governor of the steam engine, which checks and corrects any irregularities almost before they become evident; and in like manner no unbalanced deficiency in the animal kingdom can ever reach

any conspicuous magnitude, because it would make itself felt at the very first step, by rendering existence difficult and extinction almost sure soon to follow. An origin such as is here advocated will also agree with the peculiar character of the modifications of form and structure which obtain in organized beings—the many lines of divergence from a central type, the increasing efficiency and power of a particular organ through a succession of allied species, and the remarkable persistence of unimportant parts such as colour, texture of plumage and hair, form of horns or crests, through a series of species differing considerably in more essential characters. It also furnishes us with a reason for that 'more specialized structure' which Professor Owen states to be a characteristic of recent compared with extinct forms, and which would evidently be the result of the progressive modification of any organ applied to a special purpose in the animal economy.

We believe we have now shown that there is a tendency in nature to the continued progression of certain classes of *varieties* further and further from the original type—a progression to which there appears no reason to assign any definite limits—and that the same principle which produces this result in a state of nature will also explain why domestic varieties have a tendency to revert to the original type. This progression, by minute steps, in various directions, but always checked and balanced by the necessary conditions, subject to which alone existence can be preserved, may, it is believed, be followed out so as to agree with all the phenomena presented by organized beings, their extinction and succession in past ages, and all the extraordinary modifications of form, instinct, and habits which they exhibit.

TERNATE, February, 1858.

THE STORY OF THE CAHOW.

THE MYSTERIOUS EXTINCT BIRD OF THE BERMUDAS.

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WHEN the Bermudas were first visited by Europeans, about three hundred years ago, they had never been occupied by man. In this respect they differed from most islands of a similar size and blessed with a genial climate.

The study of the character of their original fauna and flora and of the changes subsequently wrought by man is, therefore, of peculiar interest. Fortunately there were several educated and intelligent men in the two parties who were wrecked upon the islands (1593 and 1609) to whom we owe the first intelligent descriptions of the islands and their products. These writers and others who settled there in 1612 to 1616, all agree in respect to the wonderful abundance of certain sea-birds, whose eggs and flesh contributed very largely to their food supply. Indeed, it is probable that without this source of food those shipwrecked parties would have died of starvation. Even later, in 1615, during a famine that occurred among the settlers, the birds furnished for a time a large part of their food. One of these abundant and useful birds they called the 'egg-bird,' because its spotted eggs were laid in vast numbers, openly, in May, on some of the smaller sandy islands 'reserved for their use.' This was undoubtedly a tern, probably the common tern, or the roseate tern, both of which were still breeding in small numbers on Gurnet Rock in 1850.

Perhaps both these species of terns were included under the general name of 'egg-birds,' for two or more species often breed together and have similar eggs. The noddy tern may also have been one of them, for it is mentioned under this name by one of the early writers.

But the terns were so continually and persistently robbed and killed that they were soon driven from their breeding grounds or exterminated. They are now known only as migrants. As breeding birds they have long been extinct at the Bermudas, the last records of their breeding being about fifty years ago. Among the formerly abundant birds there is one, however, of far greater interest: originally called the 'cahow' or 'cohowe,' with various other spellings, from its singular note. This bird is unknown to science and is, so far as known, totally extinct.

At the time of the early settlements (1612 to 1615) it bred in great numbers on some of the smaller islands and was easily captured at night. It laid a single, large, white egg, described as like a hen's egg in size, color and flavor. The nest was, according to all early writers, except one, a burrow in the sand like a coney's, and *not* in crevices of the rocks, like that of the shearwaters, with which many writers have tried to identify it. Governor Nathaniel Butler, in his 'Historye of the Bermudaes,' writing about 1619, states that its eggs and young were found in crevices of the ledges, but he probably did not have the advantage of personal experience.

The time of laying its eggs is another very remarkable thing, in which it differed from all other birds of northern latitudes. The early contemporary writers all agree that it laid its eggs 'in December and January' or 'in the coldest and darkest months of the year.' The shearwaters, even in the West Indies, lay their eggs in spring (March

CASTLE ISLAND, LOOKING SOUTH; *a*, ANCIENT RUINED FORT OR CITADEL; *b*, BARRACKS AND BATTERY; *c*, ANCIENT WALL, BROKEN DOWN AT *c'* BY THE HURRICANE OF SEPT. 12, 1899; *d*, MAIN ISLAND OF BERMUDA.

and April) and their eggs are so musky that they are not edible; certainly no one would compare them to a hen's egg. Their flesh has, also, so strong a flavor of bad fish-oil and musk that no one would eat it, unless on the verge of starvation.

The bird itself was variously described as of the size of a pigeon, green plover or sea mew; its bill was hooked and strong, and it could bite viciously; its back was 'russet brown' and there were russet and white quillfeathers in its wings; its belly was white. It was strictly nocturnal in its habits, and could be called within reach of the hand by making loud vocal notes. Its flesh was described as of excellent flavor, and for that reason it was captured at night in large numbers, while its eggs were constantly gathered for food. It arrived in October and remained until the first of June.

There is no known living bird that agrees with it in these several characters. Most certainly it could not have been a shearwater, nor any

member of the petrel family, all of which have such a disagreeable flavor that neither their flesh nor eggs are edible. It seems to me far more probable that it was allied to the auks (*Alcidæ*), many of which burrow in the ground and lay white, edible eggs. The northern auks also have edible flesh and often a strong hooked bill.

But no existing species breeds so far south, nor do they breed in winter. The cahow may have spent the summer in the southern hemisphere, but possibly it was an arctic bird that produced a southern brood in winter. Or it may have been a localized pelagic species, coming to the land only for breeding purposes.

The following graphic account of the bird and its habits was written by Mr. W. Strachy, one of the party of 150 persons who were wrecked with Sir George Somers in the 'Sea Venture,' July, 1609:

> "A kinde of webbe-footed Fowle there is, of the bignesse of an English greene Plover, or Sea-Meawe, which all the Summer we saw not, and in the darkest nights of November and December (for in the night they onely feed) they would come forth, but not flye farre from home, and hovering in the ayre, and over the Sea, made a strange hollow and harsh howling. They call it of the cry which it maketh, a Cohow. Their colour is inclining to Russet, with white bellies, as are likewise the long feathers of their wings, Russet and White, these gather themselves together and breed in those Ilands which are high, and so farre alone into the Sea, that the Wilde Hogges cannot swimme over them, and there in the ground they have their Burrowes, like Conyes in a Warren, and so brought in the loose Mould, though not so deepe; which Birds with a light bough in a darke night (as in our Lowbelling) wee caught, I have beene at the taking of three hundred in an houre, and wee might have laden our Boates. Our men found a prettie way to take them, which was by standing on the Rockes or Sands by the Sea-side, and hollowing, laughing, and making the strangest outcry that possibly they could; with the noyse whereof the Birds would come flocking to that place, and settle upon the very armes and head of him that so cryed, and still creepe neerer and neerer, answering the noyse themselves; by which our men would weigh them with their hand, and which weighed heaviest they took for the best and let the others alone, and so our men would take twentie dozen in two houres of the chiefest of them; and they were a good and well relished Fowle, fat and full as a Partridge. In January wee had great store of their Egges, which are as great as an Hennes Egge, and so fashioned and white shelled and have no difference in yolke nor white from an Hennes Egge. There are thousands of these Birds, and two or three Ilands full of their Burrowes, whether at any time (in two houres warning) wee could send our Cockboat, and bring home as many as would serve the whole Company: which Birds for their blindnesse (for they see weakly in the day) and for their cry and whooting, wee called the Sea Owle; they will bite cruelly with their crooked Bills."

The following description is taken from 'The Narrative' (1610), by Silvanus Jourdain, who was also one of Somers's party:

> "Another Sea fowle there is that lyeth in little holes in the ground, like unto Coney holes, and are in great numbers exceedingly good meate, very fat and sweet (those we had in the winter and their eggs are white, and of that

bignesse, that they are not to be knowne from these egges. The other birds egges are speckled and of a different colour."

In a letter written from the 'Summer Islands,' Dec., 1614, by the Rev. Lewis Hughes, the following account of the cahow occurs:

"Here is also plenty of sea foules, at one time of the yeare, as about the middle of October, Birds which we call cahouze and Pimlicoes come in. The Cahouze continue til the beginning of June in great abundance, they are bigger bodied than a Pigeon & of a very firm & good flesh. They are taken with ease if one do but sit downe in a darke night, and make a noise, there will more come to him then he shall be able to kill: some have told me that they have taken twelve or fourteen dozen in an hower. When the Cahouze time is out, other birds called noddies and sandie birds come in, and continue till the latter end of August."

This is the only account that gives the time of its arrival and departure.

The following extract is from Governor Butler's 'Historye,' written about 1619:

"For the cahowe (for so soundes his voice), it is a night bird, and all the daye long lies hidd in holes of the rocks, whence both themselves and their young are in great numbers extracted with ease, and prove (especially the young) so pleaseinge in a dish, as ashamed I am to tell, how many dosen of them have been devoured by some one of our northern stomacks, even at one only meale."

This is the only original statement that I find, among the early writings, that it lives in holes of rocks. It is possible, however, that it lived in all available holes, either in those made in the soil by the abundant land crabs or those found among rocks. It may not have made its own burrows, when other holes were available. Captain John Smith's account was compiled from those given above. He did not visit Bermuda.

There are several references to this bird in the local laws of Bermuda. Even so early as 1616 a law was passed restricting the taking of the bird and its eggs, because of the rapid decrease in its numbers.

It is thus referred to in Governor Butler's 'Historye.'

"In the same moneth he held his second generall Assize at St. George's, as irregularly as the first, wherin not any matter of note was handled, only a proclamation (or rather article, as it was then tearmed) was published (but overlate) against the spoyle and havock of the cahowes, and other birds, which already wer almost all of them killed and scared awaye very improvidently by fire, diggeinge, stoneinge, and all kinds of murtheringes."

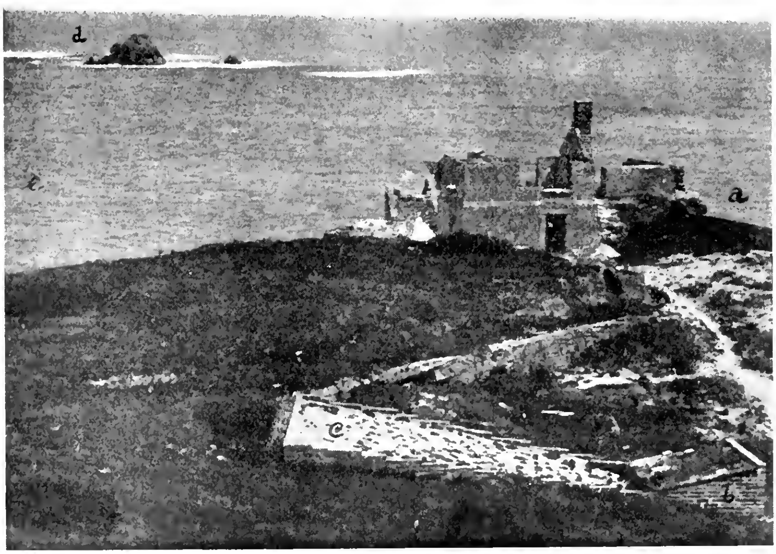
Among the laws enacted by the Bermuda Company, 1621-22, was the following:

"The Governour, and other officers, shall take care for the preservation of the breed of Birds, by reserving to them those Ilands whereunto they resort."

This doubtless refers to the egg-birds as well as to the cahow. It seems to have been almost or quite forgotten for over 200 years. In

1849, Mr. J. L. Hurdis visited Gurnet Rock or 'Gurnet Head Rock,' a small, precipitous, and nearly inaccessible outlying island, situated off Castle Harbor, and found there the nests of a shearwater *in the crevices of the rocks.* He concluded that he had found and identified the long-lost cahow.

His identification has been accepted by Capt. S. G. Reid and other later writers on the ornithology of the Bermudas, apparently without any adequate consideration of the facts stated by the early writers from personal observation. It has been assumed by nearly all recent writers, though without any real evidence, that Gurnet (Head)



Ancient ruined fort *a* on Gurnet's Head of Castle Island; *b*, water cistern, still holding water; *c*, catchment slope, built of slabs of limestone; *d*, Gurnet Head Rock; *e*, entrance to Castle Harbor.

Rock was the particular place, or at least one of the places, where the cahow bred in old times. Perhaps this may be due to the name, but it was called 'Gurnet Head Rock,' because it lies off 'Gurnet Head' on Castle Island. The latter name was in use in 1619. Some of the early writers say that it bred on some of the smaller uninhabited islands, inaccessible to the wild hogs, without designating any particular one (see Strachy's narrative). Governor Butler and the Rev. Lewis Hughes say that a boat could go to its breeding places and get a load of the bird and its eggs in a short time (see Strachy's account, above). This was apparently done only in the night. Therefore the islands visited

must have been near at hand and easily accessible, with available and safe landings, even in winter, when the eggs were sought. Gurnet Rock does not fulfill any of these conditions. It is several miles from St. George's, then the chief settlement and capital; it stands isolated outside all the other islands, so that it is exposed to the full force of the sea on all sides and in December and January the sea is always boisterous in these waters; it has no place where a boat can safely land, unless in nearly calm weather and by daylight; its sides are nearly perpendicular, exceeding rough, high cliffs, which can hardly be scaled without risk of loss of life or limbs, unless by means of ropes and ladders. Moreover the top is of very small area and almost destitute of soil. So that there is no possible chance for a bird like the cahow to burrow there. The writer, with two companions, visited this island about the first of May of this year, on a day when the sea was not very rough, and the tide was low. We found it impossible to land except by stepping out upon a narrow, slippery and treacherous reef of rotten rock and corallines, covered with sea-weeds, exposed only at low tide, and standing a little away from the shore, with deep water between. The sea was breaking over this reef, and it was difficult to wade ashore except at one place, on account of the depth of water. With the aid of a long pole I climbed partly up the side of the rock, at the only available place, and though I did not reach the summit, I could, from my highest position, see that there is no soil on the top, but only a few seaside shrubs and herbaceous plants, growing from crevices of the rock. This was sufficient to convince me that the cahow never bred on this rock, and, if it had, the early settlers would never have gone there in the winter and at night to get the eggs or birds.

It is far more probable that one of its breeding places was on Goat Island, which is a larger, uninhabited island about half a mile inside of Gurnet Rock, and with a beach of shell-sand on the inner side, where boats can safely land. Moreover on this island, in early times, there was a deep deposit of sand and soil, which was subsequently used as a burial place for soldiers who died in the old fortifications on this and the adjacent Castle Island and Southampton Island. Indeed we found two ancient human skeletons partly exposed in this bank of sand, where it had been recently undermined by the sea. Evidently a large amount of this sandy deposit, which contains fossil land snails, has been washed away since the time when the old 'Charles Fort' was built upon this island, about 1615. This old ruined fort was of small size and apparently has been abandoned since about 1630. It has the same size and form shown on Norwood's chart, published in 1626. Norwood mentions, in 1663, that it had then 'fallen into decay.' Probably the cahow may have bred also on Castle Island, which is a larger island a short distance inside Goat Island, and on Southampton Island,

Gurnet's Head of Castle Island, showing [illegible] Southampton Island and ruins of the fort, built about 1620, at entrance to Castle Harbor.

Goat Island (formerly Charles' Island), with ruins of Charles' Fort, built about 1615.

a little farther west. But these and other adjacent islands, including Cooper's Island, were fortified between 1612 and 1620, and it is probable that their occupation, at that time and later, was one of the causes of the rapid extermination of the cahow and egg-birds. We endeavored to secure some bones of the cahow by digging in the rubbish heaps about the old forts on Castle Island, but though we found numerous bones of fishes, hogs, etc., and a few of birds, none appear to belong to the cahow. But probably the deposits that we excavated were of later date, for the Castle Island forts were again garrisoned during the war of 1812. We found old silver and brass military buttons, gun flints and the cores of flint nodules, from which they had been chipped, with many other old relics, but nothing to indicate the first period of occupation, from 1614 to 1625, when alone the cahow might have formed a part of the rations.

In the 'Plain and True Relation' by the Rev. Lewis Hughes, 1621, there is a graphic account of the famine of 1615, from which the following extract is taken:

"The first night that I lay in the Iland, which you call Coopers Iland (whither the lazie starving crewe were sent, and with them some honest industrious persons, though then much out of heart, and now living, and well, thanks unto God) when I saw in every Cabbin Pots and kettles full of birds boyling, and some on spits rosting, and the silly wilde birds comming so tame into my cabbin and goe so familiarly betweene my feet, and round about the cabbin, and into the fire, with a strange lamentable noyse, as though they did bemoan us, and bid us take, kill, roast, and eate them: I was much amazed, and at length said within myselfe, surely the tameness of these wilde birds, and their offring of themselves to be taken, is a manifest token of the goodnesse of God even of his love, his care, his mercy and power working together, to save this people from starving. Mr. Moore then Governour, fearing that their overeating themselves would be their destruction, did remove them from thence to Port Royoll, where they found but little or no want; for, birds they had there also, brought to them, every weeke, from the Ilands adjoyning, whither some were sent of purpose to bird for them."

This account of the habits of the cahow would not, in the least, apply to the shearwater. It is probable, however, that the latter is identical with the nocturnal bird called 'Pimlico' by the early settlers.

The following extract from the 'Historye' by Governor Nathaniel Butler, written about 1619, relates to the famine of 1615, and shows some of the causes of the very rapid extermination of the birds:

"Whilst this Pinnace was on her way for England, scarcetie and famine every day more and more prevayleinge upon the sickly colony, caused the governour to look well about him; in the beginning of the newe yeare, therefore (1615), 150 persons, of the most ancient, sick, and weake, wer sent into Coopers Iland, ther to be relieved by the comeinge in of the sea-birds, especially the Cahowes, wher, by this half hunger-starved company, they are found in infinite numbers, and with all so tame and amazed they are, that upon the least howeteinge or noyce, they would fall downe, and light upon their shoulders

as they went, and leggs as they satt, suffering themselves to be caught faster than they could be killed." "Wittnesse the generall carriage and behaviour of this company, who being thus arrived and gott up to a libertie and choice of eateing as much as they would, how monstrous was it to see, how greedily everything was swallowed downe; how incredible to speake, how many dozen of thoes poore silly creatures, that even offered themselves to the slaughter, wer tumbled downe into their bottomlesse mawes: wherupon (as the sore effect of so ranck a cause, the birds with all being exceedeingly fatt) then sodenly followed a generall surfettinge, much sicknesse, and many of their deathes."

The chances of finding bones of the cahow would probably be better on Cooper's Island than elsewhere, if the above narratives of Governor Butler and Mr. Hughes were correct. That the latter referred to the cahow, though he did not mention the name of the 'silly birds,' may be properly inferred, because of the season, 'beginning of the newe yeare,' when the large party of starving settlers was sent there for food. The egg-birds did not arrive until the first of May. This famine and the sending of a large number of starving persons to feed on the defenceless birds, at their breeding season, was unquestionably the direct and principal cause of their rapid extermination, for it was during the very next year (1616) that the first law was passed, 'but overlate,' restricting the 'spoyle and havock of the cahowes.' We were unable, for lack of time, to dig for the bones of the cahow on Cooper's Island. The loose ground there is full of the holes of two species of large land crabs. Such holes may have served the cahow for nesting places.

PSYCHIATRY—ANCIENT, MEDIEVAL AND MODERN.

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"Forth from my sad and darksome cell,
Or from the deepe abysse of hell,
Mad Tom is come into the world againe
To see if he can cure his distempered braine."
—Old Tom O'Bedlam Song, XVII. century.

AMONG the achievements of the nineteenth century none surpass the revolution wrought in the field of psychiatry. The care of the insane to-day excites the interest not only of philanthropists and alienists, but of all right-minded men and women. "No reflecting mind," says Letchworth, "can be indifferent to the question of making proper public provision for the treatment and care of those afflicted with an insidious disease from which no measure of intellectual or physical strength or worldly prosperity affords any certain immunity —a disease, which, prone to feed upon excitement, finally transforms the noblest faculties of our race into a wreck so appalling that in its contemplation the human intelligence becomes bewildered and dismayed. At no time in the history of civilization has the importance of this subject been more thoroughly acknowledged; and probably at no time have influences contributory to mental derangement been more powerful than they are to-day." It is eminently profitable at this time to review the treatment of the insane in ancient days, to recall the misfortunes of the unhappy madman during the dark ages of history, and to note the gradual evolution of the psychiatric science of to-day.

Going back into the very dawn of history we find scattered references to the treatment of madness, which was looked upon as a punishment by the gods or ascribed to demoniacal possession. The earliest known historical reference to insanity occurs in Egyptian papyri of the fifteenth century B. C. In one of these, according to Mahaffy, music is spoken of as employed in the treatment of insanity, and many formulæ are given for the cure of diseases caused by an evil spirit dwelling within the body. Probably the next earliest record is that found in Hebrew history, referring to the same therapeutic agent, this time used to calm the troubled spirit of Saul (1055 B. C.). In the first book of Samuel we read: "When the evil spirit was upon Saul, that David took a harp and played with his hand; so Saul was re-

freshed and was well and the evil spirit departed from him." The legendary history of Greece affords numerous instances of madness, but as to the treatment in these early times there is only eloquent silence. The belief in demoniacal possession was prevalent among all primitive peoples, furnishing a clue for such treatment as was anywhere attempted, and this belief, giving way a few centuries later to a partial realization of the physical basis of insanity in the best medical minds, recurs again in the darkness and decadence of the middle ages but magnified and rendered terrible by the ignorance and gross superstitions of the time. In ancient Egypt, demons were exorcized and lunatics purified in temples dedicated to Saturn. The god Khons is said to have answered prayers for the cure of an Asiatic princess. The priests of Egypt, who were also physicians of the day, were not unmindful of the benefit of hygienic measures and combined with them the charm of music and the influence of the beautiful in nature and in art.

No reference is made in the literature of antiquity to places set apart for the care of the insane. In Greece they were sometimes cared for by the priests in the temple of Aesculapius. More often they were detained at home by their friends if dangerous, or allowed, if mild, the freedom of the country unrestrained and unmolested. Many of the soothsayers, sorcerers and sibyls of these days were undoubtedly insane, and the mental condition of some was known to those who sought their offices. Restraining devices were generally used in all violent forms of madness. Herodotus relates that Cleomenes (519–491 B. C.), king of Lacedæmon, becoming insane, was imprisoned by his kindred and his feet put in the stocks. While so bound he asked the man left to watch him for a knife. This being refused he began to threaten the man, who, becoming frightened, gave him the knife and he at once made repeated gashes in his limbs and abdomen until he died.

In the time of Euripides (480–406 B. C.) it would appear from his account of the madness of Hercules that madmen were bound with cords and fastened to the nearest convenient spot. Hippocrates, the Father of Medicine (460–377 B. C.), described three forms of mental disease and seems to have recognized alcoholic insanity. He was the first to lay stress upon the physical basis of insanity and ridicules the treatment given by the priests. He used phlebotomy, purgatives, emetics, baths, a vegetable diet, exercise, music and travel. He regulated the use of hellebore, a drug held in high esteem from the dawn of history. Writing to Democrates he said: "Hellebore when given to the sane, pours darkness over the mind, but to the insane it is very profitable." This drug was believed to act powerfully in cleansing and invigorating the intellectual faculties. It is said that Carniades, the

Academic, when preparing to refute the dogmas of the Stoics, went through a course of purgatives by hellebore. Melampus, son of Amythaon, is said to have cured the daughters of Proetus, King of Argos, of melancholy, by purging them with hellebore. According to tradition Melampus had observed that the goats who fed on this plant were purged, and having administered it to the king's daughters, who were wandering in the woods under the delusion that they were cows, he cured them and received the hand of one of them in marriage and a part of the kingdom of Argos as his reward. So celebrated was this medicinal agent as a mental remedy that the poets of antiquity sang its praises. Horace, in allusion to the 'happy madman,' says:

> He, when his friends at much expense and pains,
> Had amply purged with hellebore his brains,
> Came to himself—"Ah, cruel friends!" he cried,
> "Is this to save me? Better far had died
> Than thus be robbed of pleasure so refined,
> The dear delusion of a raptured mind."

Persius thus addresses Nero in his fourth satire, telling him to relinquish the arduous duties of government:

> "Thou hast not strength, such labors to sustain,
> Drink hellebore, my boy—drink deep and purge thy brain."

Hippocrates had his patients collect this medicine themselves at Anticyra, in Thessaly, and thus made its use an incident of a very hygienic course of treatment. In cases of suicidal melancholia he employed mandragora, first spoken of by him in the treatment of this disease.

The attitude of the state toward the care of the insane at the period soon after the death of Hippocrates is thus expressed by Plato (375 B. C.) in 'Laws of the Republic': "If any one is insane, let him not be seen openly in the city, but let the relatives of such a person watch over him at home in the best manner they know and if they are negligent let them pay a fine."

The teachings of Hippocrates and his followers were probably the guide for those who had to do with the insane during the next two centuries, and nothing further appears in medical literature until the careful study of insanity made by Asclepiades of Bythinia (100 B. C.). He distinguished between illusions and hallucinations, noted the changing mental states of individual cases and made some innovations in the treatment. He recommended his patients to be placed in the light rather than confined in dark rooms or cells, disapproved of venesection, and of the fomentations of poppy, mandragora or hyoscyamus. He prescribed abstinence from food, drink and sleep in the early part of the day; the drinking of water in the evening; that gentle friction

should be employed and, later on, liquid nourishment should be administered and the friction repeated. By these means it was his hope to induce sleep. Themison, his disciple, prescribed a more liberal diet, baths and astringent fomentations. Another of his disciples recommended stripes in the treatment of the insane, but it is doubtful if this was sanctioned by the master. Asclepiades also attempted substitutive medication, advising intoxication in the general treatment of insanity.

Celsus (A. D. 5) formulated wise rules for the hygienic and moral treatment, but unfortunately advised also the use of hunger, chains and chastisements to subjugate the patient. He would have those scolded whose mirth was excessive and resort to torment should conciliation fail. To startle a patient suddenly, to terrify him, this was excellent. But he directed that all things possible should be done to divert the melancholy and to excite cheerful hopes. Pleasure should be sought in fables and in sports, in music and in reading aloud. To quiet the excited and to favor sleep, he made use of a rocking motion and the sound of a waterfall.

Aretaeus (A. D. 80) gave a detailed description of mania and melancholia, considering the latter to be the incipient stage of the former. Little is known as to his methods of treatment, except that he does not mention restraint in his descriptions.

Galen (A. D. 150), the celebrated advocate of the humoral pathology, gives little as to treatment, but his theory of insanity is interesting. Moisture, he says, produces fatuity, dryness sagacity, and therefore the sagacity of a man will be diminished in proportion to the excess of moisture over dryness. Therefore preserve a happy medium between these opposite qualities, use venesection if you think the whole body of the patient contains melancholy blood. Bleeding must be avoided if madness arise from idiopathic disease of the brain.

Then follows Coelius Aurelianus (A. D. 195), leaving a most remarkable treatise on the treatment of insanity, preaching gentleness and humanity, skilled attendance and non-restraint. He thus expresses himself regarding the physicians who resort to harsh methods of treatment: "They seem rather to lose their own reason than to be disposed to cure their patients, when they liken them to wild beasts who must be tamed by the deprivation of food and the torments of thirst. They go so far as to counsel bodily violence and blows, as if to compel the return of reason by such provocations, a deplorable method of treatment that can only aggravate the patients' condition, injure them physically, and offer to them the miserable remembrance of their sufferings whenever they recover the use of their reason." He taught that the patient should be put in a quiet room, moderately warm and light, excluding everything of an exciting nature. The bed

should be firm and fixed to the floor and should have a straw mattress. The attendants should be carefully instructed. "If the sight of other persons irritates them and only in very rare instances, restraint by tying may be employed, but with the greatest precaution, without any unnecessary force, and after carefully protecting all the joints and with especial care to use only restraining apparatus of a soft and delicate texture, since means of repression employed without judgment increase and may give rise to furor instead of repressing it." He used fomentation by applying warm moist sponges over the eyelids to relax them and influence the circulation in the membranes of the brain. He advised emollient and astringent applications, the latter made of galls, alum, etc., soothing and invigorating poultices, baths of oil and natural hot baths. He denounced abstinence and ordered a full diet. He spoke against the practice of making the patient intoxicated, the use of hellebore, of aloes and of venesection. During convalescence he recommended farming, walking, riding, singing and theatrical entertainments. In the latter scenes of a solemn and tragic character were to be enacted to guard against excitement.

With the passing of Galen and Coelius Aurelianus the sun goes down into the black clouds of ignorance succeeding the fall of the Roman Empire; and the lunatic is left to drag out a miserable existence, generally neglected and alone throughout the dark centuries following, to and through the middle ages. There is a fitful gleam faintly illuminating the scene momentarily as when Alexander of Tralles (A. D. 560), or Paulus Aegineta (A. D. 630) reiterates the teachings of Aurelianus, but they lay stress more upon the medicinal than the hygienic treatment and are forgetful of his admonitions against chains and imprisonment. The earliest hospital for the insane known was founded in Jerusalem in the fifth century as a refuge for anchorites whose minds became affected through their penances.

The middle ages are defined by Hallam as dating from the invasion of France by Clovis at the end of the fifth century to the invasion of Naples by Charles VIII. at the end of the fifteenth. During the first half of this period there seems scarcely to have been any intellectual or political development. The whole of Europe was, almost without exception, sunk in the darkest ignorance and the most wretched barbarism. In some countries the awakening was earlier than in others, but the darkness did not anywhere die out at once. As gradually the clouds began to lift and the signs of returning light were here and there discernible only a fraction of a special class, a limited portion of the clergy, were in any way affected, and the mass remained for long bound down by servility, ignorance and superstition. "The struggle among the races for the possession of the countries that had been loosed from the Roman yoke," says Sibbald, "'continued for centuries

to make the state of war persistent and almost universal." When not in conflict with their neighbors, the constant friction and strife within the individual states still prevented organization and natural development. "In such a state of society little thought could be bestowed on anything which did not directly relate to the fierce struggle for very life in which every state and every individual was engaged." There was no time for philanthropy, for the care of the suffering, for the relief of the poor, for comforting the sick in body or mind. Slowly the leaven of christianity was at work, a silent force effecting slow but deep-rooted changes in the constitution of society, beginning about the eleventh century to gradually bring about the abolition of slavery and exerting an influence in instituting some sort of provision for those whose mental condition was thought to be the result of disease. The monks were also the physicians during the dark ages and the monasteries offered quiet retreat and seclusion for many insane, together with sympathy and protection which could not be found elsewhere. Spiritual agencies were everywhere popularly believed to be most efficacious in the cure of madness, and many and long were the pilgrimages made to the shrines of those saints who were believed to have special influence over the mentally afflicted, and many miraculous cures were said to have been brought about through exorcism and prayer. There were many wells through Europe and the British Isles, each with its particular saint, to which the insane were brought to bathe and to pray. At St. Nim's Pool in England, it was the custom to plunge the patients backwards into the water and drag them to and fro until their excitement was subdued. If they showed signs of recovery thanks were offered in a neighboring church, but if not, the treatment was continued until no hope remained. From the seventh century even to the present day lunatics have made pilgrimages to the shrine of St. Dymphna at Gheel, and here the first colony for the insane originated through a slow process of evolution, and stands to-day as the best representative of the community or family system of caring for the insane.

So great a part did superstition and religious bigotry play in the treatment of insanity that the estate of the lunatic grew ever worse. Any man who exhibited anything unusual in conduct or language was at once suspected by his neighbors of necromancy or commerce with the Devil and looked upon with suspicion. Any manifestation of peculiar genius, the display of inventive ability or promulgation of a new doctrine rendered a man liable to torture, imprisonment or death. The belief in demoniacal possession, and witchcraft, was distinctly recognized in the Bible and fostered by the church. All over Europe persons undoubtedly insane were burned or hanged as witches or were whipped in the public squares to drive out the evil spirits.

Pope Innocent VIII. in 1488 appointed inquisitors in every country armed with apostolic power to find and punish those of whom he thus declared: "It has come to our ears that numbers of both sexes do not avoid to have intercourse with the infernal fiends, and that by their sorceries they afflict both man and beast. They blight the marriage bed; destroy the births of women, and the increase of cattle, they blast the corn in the ground, the grape in the vineyard, the fruit of the trees, and the grass and herbs of the field." Thus stimulated by the church the search for persons punishable for these crimes was everywhere successful. It is probable that one-fourth of the 40,000 persons executed for witchcraft during the first eighty years of the seventeenth century in England alone were insane. Among the thousands of persons tortured, burned and hanged as heretics there were doubtless many who, infected by surrounding fanaticism and carried away by exceptional beliefs, were really the victims of mental disease.

Persons afflicted with the more quiet forms of insanity without excitement were often regarded as suffering in punishment for sin and were accordingly treated by fasting, pilgrimages and self-castigation. Some, the possessors of a certain shrewdness and drollery, were received into private houses and cared for, partly from charity, and partly because of the amusement to be derived from their eccentric speech and conduct. The conditions were practically the same in all European countries with the exception of Italy and Spain, where insane asylums were established during the latter part of the middle ages.

The Mohammedans preceded the Christians in the establishment of asylums for the insane, and it is probable that as early as 1300 A. D. this form of charity was general in Mohammedan countries. A writer of the seventh century notices the existence of several such institutions at Fez. The asylum in Cairo was founded in 1304 A. D. Whether or not the Christians obtained the idea of the organization of such asylums from the Mohammedans, it is of interest to note that they are first found in Europe among those nations nearest to the Mohammedans and most subject to their influence. To Spain is due the honor of establishing the first asylum in Christian Europe for the care of the insane exclusively. This was opened in Valencia in 1409 A. D. by a monk, Juan Gilaberto Joffre, who was moved by compassion on seeing maniacs driven through the streets by hooting crowds of men and boys. The treatment in these early establishments amounted to little more than seclusion and restraint, though the monks in charge of the asylum at Saragossa, established in 1425 A. D., had some conception of a rational open air treatment. Asylums were also opened at Seville and Valladolid in 1436 A. D. and at Toledo in 1483 A. D. "Two other very honorable facts may be mentioned," says Lecky, "establishing the preeminence of Spanish charity

in this field. The first is that the oldest lunatic asylum in the metropolis of catholicism was that erected by the Spaniards in 1548. The second is, that, when at the close of the eighteenth century, Pinel began his great labors in this sphere, he pronounced Spain to be the country in which lunatics were treated with most wisdom and most humanity."

In the twelfth century madmen were taken to St. Bartholomew's in London and, according to the monkish narratives many wonderful cures were effected. Up to the sixteenth century monasteries and prisons and ecclesiastical hospitals contained cells into which lunatics were received, but it is probable that they were given little care or treatment and that the public at large was the chief beneficiary by their incarceration. In 1547 the first lunatic asylum not under ecclesiastical administration was established in England. The priory for the order of St. Mary of Bethlehem founded by Simon Fitzmary, a sheriff of London, in 1247, in St. Botolph's without Bishopsgate, London, had for a century and a half been used for the reception of lunatics. In this year the institution, for long before called Bedlam, was transferred by Henry the VIII. to the authorities of the city, with an order that it be converted into a house for the reception of lunatics. It stood in an out of the way place, close to many common sewers and accommodated but fifty or sixty patients. For very many years, however, the place remained a 'horrible prison,' says Sibbald, 'and not a hospital in any sense of the word.' "Up to the year 1770 the patients were exhibited to the public like wild beasts in cages, on payment of a penny, and they are said to have afforded much sport to the visitors who flocked to see them in numbers estimated at not less than 48,000 annually. Some whose condition was so ameliorated that they were no longer considered dangerous to the public were licensed to go begging. On their left arm was placed an armilla—an iron ring for the arm about four inches long, which they could not get off." "They wore about their necks," says Aubrey, as quoted by Disraeli, "a great horn of an ox in a sling or bawdry, which when they came to a house they did wind; and they put the drink given them into this horn, whereto they put a stopple." In a Tom of Bedlam song which dates from the first part of the seventeenth century, the comforts of his asylum life are thus alluded to by the licentiated beggar:

> In the lovely lofts of Bedham
> In stubble soft and dainty,
> Brave bracelets strong,
> Sweet whips ding dong,
> And a wholesome hunger plenty.

About 1675 when the licensing of beggar lunatics was stopped by law, a new Bedlam three times the capacity of the old was erected in

Moorfields, the necessity for increased accommodations becoming greater 'as the country came more and more into systematic government and as the wholesale burning of such unfortunate persons as wizards or witches died out.'

Little appeared in medical literature during this period upon the care of the insane. Daniel Sennert (1572–1637) wrote sensibly upon mania and melancholia, but left nothing as to treatment, except to bleed and to purge. Sydenham (1624–1689) had little to say on mental affections. An adherent to the current doctrine, he attributed insanity to a disabling of the 'animal spirits' by a prolonged fermentation. He prescribed a cordial of Venice treacle, containing the flesh and broths of vipers, amber and sixty-one more ingredients in Canary wine and honey to be given three times a day, the patient to remain in bed and to be liberally supplied with liquids. For ordinary mania he ordered the withdrawal of nine ounces of blood on two or three occasions with three days' interval between each bleeding. A course of pills of colocynth and scammony followed, and on the days when the patient did not take the pills he was to have an electuary composed of conserve of monk's rhubarb, rosemary, candied angelica and other pleasant ingredients.

Something more rational was attempted in Paris when by an Act of Parliament in 1660 the insane passed through two wards, especially reserved for them in Hotel Dieu, the ward St. Louise for men containing ten beds for four each and two small beds; the ward St. Martin for women containing six large beds and six small ones. Treatment here was by means of douches, cold baths, repeated bleedings, hellebore, purgatives and antispasmodics. If there was no improvement in a few weeks they were sent to the Petits Maisons, the Salpêtrière or the Bicêtre, where they were kept clothed in rags, confined by chains, poorly fed, bedded on rotten straw, often in cells infected with disease. As in England on holidays they were exposed to the gaze of the public, admitted for a small fee as to a menagerie. In 1667 Dennis, in Paris, successfully employed transfusion of blood taken from a calf in the case of a young man insane after an unhappy love affair.

The early years of the eighteenth century saw the gradual evolution of the asylum idea and the slow increase in the number of establishments for the insane, founded not only by the state but by private individuals. The condition of the insane in the latter was particularly distressing for many years, and, even until well on in the last century, many of them were more to be dreaded than the larger public asylums.

Dean Swift had in mind the foundation of a hospital for the insane as early as 1731 when he wrote the verses on his own death and described his determination thus,

He gave the little wealth he had
To build a house for fools and mad;
And shewed by one satiric touch,
No nation wanted it so much.

This object he had afterward always in mind, and, although suffering much for several years and his mind finally becoming affected in 1742, he made plans for its establishment and, dying in 1745, left his whole property, about $60,000, for the founding of St. Patrick's Hospital in Dublin, which was opened in 1757 for the reception of fifty patients.

The methods of treatment employed in the middle of the eighteenth century are thus set forth by Dr. Richard Mead, physician to George II. in his "Medical Works" (1762). "Authors, both ancient and modern, recommend a great number of medicines, some which are suitable to maniacal, others to melancholy patients; but both sorts agree in the property of correcting the bile, which is acrid at first, then becomes viscid and black as pitch. Moreover the very blood in this disorder is thick, fizy and black. Now it will be observed that most of the medicines proper to be given in this disease are in some degree endowed with the property of opening and scouring the glands and increasing perspiration. Of this kind are the strong-smelling gums, specially asafœtida, myrrh, Russian castor, and camphire, which last is asserted to have an anodyne quality and to procure sleep with greater certainty and safety than opium. In melancholic cases chalybeats are also very proper. In fine, a frequent use of the cold bath is very serviceable, especially in maniacal cases. For nothing, as Celsus says, is of such benefit to the head as cold water." He cautions against the use of stripes or other rough treatment as unnecessary, binding alone being sufficient to restrain the maniacal, who 'are all cowards.' He attempted to stop the ill-timed fits of laughter of some by chiding and threatening; to dissipate the gloomy thought of others by music and such diversion as they formerly took delight in. He cautioned the physician to attend carefully to the free action of the bowels and kidneys and instead of applying blisters to the head he says, "Better in imitation of the ancients to shave the head, and then rub it with vinegar in which rose flowers or ground-ivy leaves have been infused; and also to make a drain by passing a seton in the nape of the neck, which is to be rubbed with a proper digestive ointment and moved a little every day, in order to give a free issue to the purulent matter." He ordered slender diet, mostly of gruels and meats easy of digestion, disapproved of giving anodynes to procure sleep and recommended walking, riding, playing at ball, swimming and travel by land or sea in convalescence.

The latter part of the eighteenth century witnessed an awakening

of the minds of men throughout the civilized and enlightened nations of the world to a realization of the man's duty to his fellow man. The dissemination of knowledge among the people was gradually killing out the grosser forms of superstition, holding such a hypnotic influence over the ignorant. The spirit of liberty, fraternity and equality was abroad. With this zeal for the acquirement of knowledge, the spirit of investigation and the kindling of enthusiasm for scientific research, philanthropic ideas began to develop in men's minds, pity for the suffering and the unfortunate and a desire to better the condition of all. Prison reform was agitated, hospitals were organized for the sick in body. The treatment of the insane was made a matter for legislative investigation and although little or nothing was done toward the immediate relief of their condition, yet public sentiment was being slowly aroused in their behalf. Gradually the light of a brighter day was dawning. The propriety of abusive treatment, of cruelty, of chains, of stripes, formerly regarded as essential for the control of the maniac, or looked upon with indifference, was now brought into question. Much was written relative to insanity during this period but no decided step was taken for the betterment of conditions until near the close of the century when the noble-hearted Tuke, in England, and the brave Pinel, in France, started the grand reform, broke the fetters and brought the great restorative, hope, to stimulate the weakened mind.

The York Asylum, founded by general subscription in 1777, for 'the decent maintenance and relief of such insane persons as were in low circumstances' was, about 1791, the worst among the bad institutions in England. In this year a young woman, a member of the Society of Friends was committed to the York Asylum. Her friends were denied the privilege of seeing her and in a few weeks she died. Her death arousing suspicion of improper treatment among the Friends, one of their number, Mr. William Tuke, "resolved (1792) to establish an institution in which there would be no secrecy and where the patients would have humane and judicious care." Thus was the Retreat at York established and, in 1796, launched upon its memorable career, continuing from the first a leader in psychiatric progress.

The year 1792 also is made memorable by the appointment of Philip Pinel as physician to the insane at the Bicêtre. Coming to this position a trained alienist, he was deeply stirred by the condition of the men confined there, fifty of them in chains, many for a long period of years. His repeated and persistent appeals to the Commune for authority to release them from their bonds were finally given a reluctant affirmative answer, and in the end he was able to remove the chains from all the patients and to continue the good work at the Salpêtrière, an institution exclusively for women.

Turning now to our own country we find the care of the insane in the American colonies prior to the Revolution to differ in no way from the treatment during the same period in Europe. In the Old Colony Laws of Plymouth (1660) provision was made that persons who commit suicide "shall be denied the privilege of being buried in the common burying place of Christians, but shall be buried in some common highway, where the selectmen of the town where such persons did inhabit, shall appoint, and a cartload of stones laid upon the grave, as a brand of infamy, and as a warning to others to aware of the like damnable practice." In jails, almshouses and the outhouses of private dwellings, the insane were kept, often in chains and in filth, and deprived of light and proper warmth. No attempt was made toward special provision for them until 1745, when an asylum was erected in New York City, on the spot where the City Hall now stands, for the reception of the 'indigent poor, the sick, the orphan, the maniac and the refractory.' But the first institution in America for the remedial treatment of the insane was founded in 1751 in connection with the Pennsylvania Hospital. Being opened 1752, "it was," says Kirkbride, "for a long period of years far in advance of all other receptacles for the insane in the United States, and, having the advantage of physicians like Bond, Shippen, Rush, Wister, Physick and others of equal ability, its wards were constantly filled, and its advantages eagerly sought by patients from the most distant parts of the Union."

It is noteworthy that, besides Dr. Thomas Bond, of Philadelphia, and Benjamin Franklin, the Society of Friends was active in the inception of this hospital, a society later to be influential in the establishment of the York Retreat in England and the Friends Asylum at Frankfort, Pa. (1813), showing in these early times a more enlightened philanthropy than any other religious body and giving the impetus to a movement which in the early years of the nineteenth century was to effect a revolution in the treatment of the insane.

The first governmental institution in America was erected by the province of Virginia at Williamsburgh in 1773; but it was not until the era of peace and quietude following the wars of the Revolution and of 1812, and after the successful inauguration of the state governments that public sentiment became thoroughly aroused to the necessity of better care for these unfortunates, and state institutions sprang into existence. During the thirty years following the war of 1812 twenty-three public and private asylums were opened in the United States.

The treatment at this time was largely influenced by the writing of Dr. Benjamin Rush, a man of great intelligence and benevolence whose 'Observations on Diseases of the Mind' (1812) contained much of

value as to the moral treatment of the insane, but who was behind Pinel in realizing the advantage of kind treatment and the harmfulness of restraint. "A prevailing error found in his writings on insanity," says a writer in the 'American Journal of Insanity' (Vol. 4) "is that the insane are to be disciplined and governed, that those who have the care of them must obtain dominion over them by fear or by other means that we may think improper." He says that the physician on entering the chamber of the deranged person should first 'catch his eye and look him out of countenance.' After trying many ways to obtain obedience he says, "If these prove ineffectual to establish a government over deranged persons, recourse should be had to certain modes of coercion." Among them were the straight jacket, the tranquilizing chair (invented by a Dr. Darwin and consisting of a stout post revolving on a pivot and bearing a chair into which the patient was bound in the longitudinal position when a sedative effect was desired or in an erect position to secure intestinal action), the withdrawal of pleasant food and pouring cold water down the coat sleeves. "If all these modes of punishment should fail of the intended effect," he adds, "it will be proper to resort to the fear of death."

But the man who did more than any other, probably, to forward the humane care of the insane, was Esquirol, who succeeded Pinel at the Salpêtrière in 1810. Devoting himself with zeal and with singleness of purpose to this ministration, he brought about still greater reforms in the housing, the regimen and medical care of the insane, and in 1817 gave the first course of lectures ever delivered on insanity. These were largely attended every year by physicians from all countries. He traveled through France investigating everywhere the condition of the insane, arousing the interest of the magistrates and, through his reports to the superior authorities, causing the abolition of many abuses and much misery. He saw ten asylums opened in France and the insane taken from 'their narrow, filthy cells, without light and air, fastened with chains in these dens,' in which he found them, and placed in asylums where the use of chains was abandoned, where walks and gardens were accessible, and where beds and good food were provided and the attendants did not go 'armed with sticks and accompanied by dogs.'

The same spirit of progress was now abroad in every enlightened country of Europe and in America. Asylums were built, treatises upon mental medicine became more numerous, classification of mental disease and more careful clinical studies were attempted, societies were organized for the study of insanity and periodicals appeared whose pages were given wholly to the discussion of psychiatric subjects and the propagation of the new doctrines.

"In the period which elapsed from 1830 to 1850," says Letchworth,

"great and rapid advances were made throughout the United States in methods of caring for the insane. The reforms then accomplished attracted the attention of Europe, and it may be said, without any egotism, that they were in advance of contemporary progress in other countries." Much of this reform was due to the exertions of Dorothea L. Dix, who about 1837 began a career of remarkable success in arousing public attention and securing legislative action for the betterment of the condition of the insane. She is said to have been influential in the establishment of thirty-two asylums for the insane. But unfortunately this high standard of achievement was not maintained. During the civil war and the early period of reconstruction this reform suffered a reaction, and the country failed to keep pace with the progressive movement in other lands. Within the last thirty years of the century, however, rapid advance was made, and to-day the standard of work done for the insane in America is not lower than that attained in other countries.

The period of large and imposing buildings, palatial in exterior appearance, has passed. The buildings erected twenty or thirty years ago were uniformly massive, three- or four-story structures, the interiors often monotonous and cheerless. To-day the tendency is to place the patient in surroundings as cheerful and homelike as possible. To have smaller buildings, comfortably furnished, with pictures on the walls, with books, games and the means for light amusements and employment. No longer is the patient forced to pace ceaselessly long cheerless corridors, the walls lined with benches and heavy chairs and bare of all adornment.

Now, instead of large blocks of buildings, the modern hospital consists of a group of cottages, best of two stories, separated or connected by a low corridor. Here the patients are separated into small groups carefully classified as to their mental condition. These buildings are surrounded by nicely kept grounds, with green lawns dotted with shrubbery and flowers. There are groves to afford a shady retreat, and here the patients spend much time every pleasant day. Many of them have the parole of the grounds and come and go without oversight. Freedom is allowed as far as is consistent with safety. In many places the usual iron gratings have been removed from the windows and doors left unlocked.

But the institutions for the insane of to-day are not places merely of detention. The insane asylum, except for the chronic cases, in most states both here and abroad, has passed away and in its place has arisen a hospital to which the patient comes as a sick man to have the kind care and systematic treatment that the word hospital implies. He is received and cared for by nurses trained to the work and is at once impressed with the idea that he is a sick man, so regarded by his fellow

men, if not cognizant of it himself, and that he is to have done for him what careful nursing, hygienic surroundings and medical science can do. The perfection to which this system has attained varies much in different states; but all are tending to the same end, and ere long the care of the acute insane in all enlightened lands will be based upon the same scientific plan. At the present time in Europe and America there is great activity within the walls of the hospitals for the insane. The study of the individual patient is more thorough than ever before. Not only are his mental symptoms diligently watched and recorded, but a careful systematic examination of all his bodily functions is undertaken. For this purpose laboratories are equipped and men trained to microscopical and chemical analysis are being more and more employed to carry on the work. The study of the physiology and pathology of the nervous system is being assiduously pursued and recent epoch-making discoveries in tissue-staining have stimulated this work, causing almost a revolution in the theories of nervous action; and it would seem that a better understanding of the functioning of the central nervous system was dawning. The defects of distant organs, of the blood vessels, the blood, the lymph and all abnormal bodily conditions, are known to often have a deleterious effect upon the nervous system and improvement in the mental condition to be coincident with their removal. The physician and the surgeon, the neurologist, the psychologist, the chemist and the pathologist are all at work hand in hand with the alienist to cure him who is the unhappy victim of mental disease.

In the modern hospital such moral measures are brought into operation as the companionship of a kind and congenial nurse, cheerful environment, the use of the minimum amount of restraint consistent with safety and efforts to amuse and divert the attention of the patient away from himself and his troubles, the attempt to arouse an interest in some light employment and the suggestive influence of a hopeful spirit. The therapeutic effect of exercise, massage, hydrotherapy and electrical influence are all called into use, and the medical treatment is directed to any complicating disorder of the bodily functions. No part is overlooked. The physical machine is restored as far as possible to working order in the hope that mental restoration will be the consequence. In a hospital thus conducted harsh or abusive treatment means the immediate dismissal of the offender.

The selection of an efficient corps of attendants is a matter of the greatest importance. Much improvement has been brought about by the establishment of training schools in hospitals for the insane with systematic instruction in the duties of the nurse. In a large and well organized institution an attendant entering the school is in a position to obtain instruction of so much general usefulness in the

treatment of the sick that the hospital benefits not only by the more efficient service rendered, but also by the attraction of a superior class of applicants for the positions. "Much has been accomplished in rescuing the insane from chains, gloomy cells and scourgings," says Letchworth, "but the measure of reform in their behalf will not be complete until there is no possibility of their being subjected to the humours of ignorant, unfeeling and incompetent attendants." That training schools are an efficient means of accomplishing this reform there can be no doubt.

A most notable advance in the treatment of the insane was the introduction of the system of non-restraint—the disuse of all mechanical devices for restraining the freedom of bodily movement. This was first demonstrated to be practicable by Mr. Gardner Hill at the Lincoln Asylum, England, in 1836, and Dr. Connolly put the system into full operation at Hanwell in 1840. At first ridiculed as "the freak of an enthusiastic mind, that would speedily go the way of all such new-fangled notions" it was bitterly opposed for years by the superintendents of the large county asylums of England, and to Dr. Connolly is due the honor of having demonstrated its practicability and of having overcome after a prolonged struggle the opposition and prejudice against it. Men like Todd, Woodward, Butler, Ray—names memorable in the history of American psychiatry—were not unmindful of the remedial value of sympathetic and kindly treatment, and, while the controversy over non-restraint was waged abroad, were independently carrying out the same humane doctrine and conducting their institutions on the same 'enlightened principles of conciliation and kindness.' At the present day the system of absolute non-restraint is more in vogue in England than here where the necessity for some form of restraining appliance is still maintained to exist in certain instances. But it is evident from the annual reports of the American hospitals that the use of restraint is lessening each year. In some institutions it is entirely abolished; in all it is used to a very limited extent and only upon the order of the attending physician. The means of restraint employed consist chiefly of the canvas camisole to restrain the movements of the hands and arms, the canvas or leather muff for the hands and the use of a strong sheet fastened across the bed if the patient is not in a conditon to be up and about the rooms. In place of the sheet the hands and the feet may be restrained while the patient is in bed by soft rolls of cheesecloth.

The most recent advance in the care of the acute insane is in the movement toward the establishment of psychopathic hospitals for treatment and for clinical and pathological research in or near the large centers of population. In this most advanced work Europe has taken the lead, and such hospitals have been in existence for some years in

the university towns of Germany and Austria. That at Giessen, opened in 1896, is thus described by Dr. Frederick Peterson, president of the New York State Lunacy Commission—"It is in the town of Giessen, near the other hospitals used for teaching purposes, adjacent to the pathological institute, and consists of ten or eleven cottages for 116 patients, in a beautiful garden. The central building contains pathological, chemical, microscopical, photographic and psychophysical laboratories, besides a mechanical workshop, clinical auditorium, library, and a dispensary or polyclinic for outdoor patients. The necessary administrative offices and rooms for the director and assistant physicians are also here. There are cottages for private cases, and for quiet, suicidal, restless, and disturbed patients of each sex. This is probably the most complete hospital of its kind in existence at the present time." Although as yet in Great Britain and America this work has not received the attention it merits, a beginning is being made. At Albany, New York, a pavilion has been opened in connection with the Albany General Hospital for the reception of the acutely insane, and in Michigan the last legislature passed an act to "Provide for the Construction of and Equipping of a Psychopathic Ward upon the Hospital Grounds of the University of Michigan." In Boston and Philadelphia out-patient departments have been in successful operation for several years. There is no doubt but that the next few years will see the general opening of such hospitals and out-patient departments in the larger cities throughout the country.

Another movement that is ripening to fruition in America is that for the establishment of 'After-care Associations' for the protection and help of needy patients upon discharge from hospitals, recovered, but without means of support. This idea originated in Germany as far back as 1829, with Hofrath Lindpaintner, who organized in that year a 'Society of Patronage' which exercised a paternal care over, and rendered assistance to, such persons for a period of two years following their recovery. Such associations were later formed in France, and in recent years the system has been in general operation in Germany, France, England and notably in Switzerland. The work of these organizations, the establishment of which in this country has already been discussed by the American Neurological Association, consists in finding proper homes and employment for discharged patients, maintaining a general supervision over them and offering such financial or other aid as may be necessary again to put them in the way of earning a livelihood.

In spite of all efforts put forth to cure the acute mental troubles a large percentage of the cases prove rebellious and drift into chronic states of mental deterioration. The patients do not die, but live in good bodily health with intellect dulled to the higher interests of life

and sink slowly into incurable dementia. Other cases are marked from the outset by the stigmata of chronicity, being slow and insidious in development, and the disease is often fully established before the patient's friends awake to a realization of the event. These chronic classes of the insane require a specialized treatment, a home where they can be protected from the world and from themselves, where congenial occupation may be obtained, where a strict but humanely enforced control may be exercised over their conduct and where their lives may be lived in comfort and in peace. Until recent years all classes of insane have been cared for in large institutions where proper classification has been difficult or impossible and where the acute and curable cases have been in daily contact with the incurable and the demented.

Of late much effort has been made to overcome this objectionable state of thing by the establishment of colonies, where the chronic insane may live in small separated cottages scattered in groups over a large tract of land. Here the patients live in small groups or families under conditions more approximating home surroundings. The farm and industrial shops furnish the occupation so necessary to relieve the monotony of life and to counteract abnormal tendencies. The little colony has its chapel and amusement hall, sometimes a store, and furnishes an environment in which a man may live in comparative comfort and with a reasonable degree of contentment. Such colonies are now quite numerous in Europe and America and seem to furnish ideal conditions for the care of the chronic and presumably incurable cases. In Scotland, Germany, Belgium, and to a limited extent in Massachusetts, a system is in operation with a fair degree of success in which selected chronic cases are boarded out in private families in the country districts while under the observation and control of a governmental bureau or commission.

It is unfortunately a fact that many of the chronic insane are still detained in almshouses and poor farms not only in this country but abroad. Here they, who are the unfortunate victims of disease and not to be held responsible for their condition, are obliged to associate with paupers and criminals and are kept in a condition unworthy of the civilization of the twentieth century. The cruelty of a past age still lingers in many of these places, and not only do they suffer from the stigma of their associations, but are too often the victims of improper and insufficient attendance and are not strangers to bonds and chains.

But the grand work of emancipation is still going on, and enlightened public sentiment is everywhere at work and the realization of a fuller charity is surely not long to be delayed. At the beginning of the twentieth century we are on the threshold of a new era in the working out of this great problem, and the scientific and philanthropic spirits of the day are laboring together and energetically toward its ultimate solution.

THE NATIONAL CONTROL OF EDUCATION.*

BY THE RIGHT HON. SIR JOHN E. GORST, F.R.S.

THE invitation of the British Association to preside over the Section of Education, established this year for the first time, has been given to me as a representative of that government department which controls the larger, but perhaps not the most efficient, part of the education of the United Kingdom. The most suitable subject for my opening address would therefore seem to be the proper function of National Authority, whether central or local, in the education of the people; what is the limit of its obligations; what is the part of education in which it can lead the way; what is the region in which more powerful influences are at work, and in which it must take care not to hinder their operation; and what are the dangers to real education inseparable from a general national system. I shall avoid questions of the division of functions between central and local authorities, beset with so many bitter controversies, which are political rather than educational.

In the first place, so far as the mass of the youth of a country is concerned, the public instructor can only play a secondary part in the most important part of the education of the young—the development of character. The character of a people is by far its most important attribute. It has a great deal more moment in the affairs of the world, and is a much more vital factor in the promotion of national power and influence, and in the spread of Empire, than either physical or mental endowments. The character of each generation depends in the main upon the character of the generation which precedes it; of other causes in operation the effect is comparatively small. A generation may be a little better or a little worse than its forefathers, but it cannot materially differ from them. Improvement and degeneracy are alike slow. The chief causes which produce formation of character are met with in the homes of the people. They are of great variety and mostly too subtle to be controlled. Religious belief, ideas, ineradicable often in maturer life, imbibed from the early instruction of parents, the principles of morality current amongst brothers and sisters and playmates, popular superstitions, national and local prejudices, have a far deeper and more permanent effect upon character than the instruction given in schools

* Address of the president of the Educational Science Section of the British Association for the Advancement of Science. Glasgow, 1901.

or colleges. The teacher, it is true, exercises his influence among the rest. Men and women of all sorts, from university professors to village dames, have stamped some part of their own character upon a large proportion of their disciples. But this is a power that must grow feebler as the number of scholars is increased. In the enormous schools and classes in which the public instruction of the greater part of the children of the people is given, the influence on character of the individual teacher is reduced to a minimum. The old village dame might teach her half-dozen children to be kind and brave and to speak the truth, even if she failed to teach them to read and write. The headmaster of a school of 2,000 or the teacher of a class of eighty may be an incomparably better intellectual instructor, but it is impossible for him to exercise much individual influence over the great mass of his scholars.

There are, however, certain children for the formation of whose characters the nation is directly responsible—deserted children, destitute orphans and children whose parents are criminals or paupers. It is the duty and interest of the nation to provide for the moral education of such children and to supply artificially the influences of individual care and love. The neglect of this obligation is as injurious to the public as to the children. Homes and schools are cheaper than prisons and workhouses. Such a practice as that of permitting dissolute pauper parents to remove their children from public control to spend the summer in vice and beggary at races and fairs, to be returned in the autumn, corrupt in body and mind, to spread disease and vice amongst other children of the State, would not be tolerated in a community intelligently alive to its own interest.

A profound, though indirect and untraceable, influence upon the moral education of a people is exercised by all national administration and legislation. Everything which tends to make the existing generation wiser, happier or better has an indirect influence on the children. Better dwellings, unadulterated food, recreation grounds, temperance, sanitation, will all affect the character of the rising generation. Regulations for public instruction also influence character. A military spirit may be evoked by the kind of physical instruction given. Brutality may be developed by the sort of punishments enjoined or permitted. But all such causes have a comparatively slight effect upon national character, which is in the main the product for good or evil of more powerful causes which operate, not in the school, but in the home.

For the physical and mental development of children it is now admitted to be the interest and duty of a nation in its collective capacity to see that proper schools are provided in which a certain minimum of primary instruction should be free and compulsory for all, and, further, secondary instruction should be available for those fitted to

profit by it. But there are differences of opinion as to the age at which primary instruction should begin and end; as to the subjects it should embrace; as to the qualifications which should entitle to further secondary instruction; and as to how far this should be free or how far paid for by the scholar or his parents.

The age at which school attendance should begin and end is in most countries determined by economic rather than educational considerations. Somebody must take charge of infants in order that mothers may be at leisure to work; the demand for child labor empties schools for older children. In the United Kingdom minding babies of three years old and upwards has become a national function. But the infant 'school,' as it is called, should be conducted as a nursery, not as a place of learning. The chief employment of the children should be play. No strain should be put on either muscle or brain. They should be treated with patient kindness, not beaten with canes. It is in the school for older children, to which admission should not be until seven years of age, that the work of serious instruction should begin, and that at first for not more than two or three hours a day. There is no worse mistake than to attempt by too early pressure to cure the evil of too early emancipation from school. Beyond the mechanical accomplishments of reading, writing and ciphering, essential to any intellectual progress in after life, and dry facts of history and grammar, by which alone they are too often supplemented, it is for the interest of the community that other subjects should be taught. Some effort should be made to develop such faculties of mind and body as are latent in the scholars. The same system is not applicable to all; the school teaching should fit in with the life and surroundings of the child. Variety, not uniformity, should be the rule. Unfortunately the various methods by which children's minds and bodies can be encouraged to grow and expand are still imperfectly understood by many of those who direct or impart public instruction. Examinations are still too often regarded as the best instrument for promoting mental progress; and a large proportion of the children in schools, both elementary and secondary, are not really educated at all—they are only prepared for examinations. The delicately expanding intellect is crammed with ill-understood and ill-digested facts, because it is the best way of preparing the scholar to undergo an examination test. Learning to be used for gaining marks is stored in the mind by a mechanical effort of memory, and is forgotten as soon as the class-list is published. Intellectual faculties of much greater importance than knowledge, however extensive—as useful to the child whose schooling will cease at fourteen as to the child for whom elementary instruction is but the first step in the ladder of learning—are almost wholly neglected.

The power of research—the art of acquiring information for

oneself—on which the most advanced science depends, may by a proper system be cultivated in the youngest scholar of the most elementary school. Curiosity and the desire to find out the reason of things is a natural, and to the ignorant an inconvenient, propensity of almost every child; and there lies before the instructor the whole realm of nature knowledge in which this propensity can be cultivated. If children in village schools spent less of their early youth in learning mechanically to read, write and cipher, and more in searching hedgerows and ditch-bottoms for flowers, insects, or other natural objects, their intelligence would be developed by active research, and they would better learn to read, write and cipher in the end. The faculty of finding out things for oneself is one of the most valuable with which a child can be endowed. There is hardly a calling or business in life in which it is not better to know how to search out information than to possess it already stored. Everything, moreover, which is discovered sticks in the memory and becomes a more secure possession for life than facts lazily imbibed from books and lectures. The faculty of turning to practical uses knowledge possessed might be more cultivated in primary schools. It can to a limited extent, but to a limited extent only, be tested by examination. Essays, compositions, problems in mathematics and science, call forth the power of using acquired knowledge. Mere acquisition of knowledge does not necessarily confer the power to make use of it. In actual life a very scanty store of knowledge, coupled with the capacity to apply it adroitly, is of more value than boundless information which the possessor cannot turn to practical use. Some measures should be taken to cultivate taste in primary schools. Children are keen admirers. They can be early taught to look for and appreciate what is beautiful in drawing and painting, in poetry and music, in nature, and in life and character. The effect of such learning on manners has been observed from remote antiquity.

Physical exercises are a proper subject for primary schools, especially in the artificial life led by children in great cities: both those which develop chests and limbs, atrophied by impure air and the want of healthy games, and those which discipline the hand and the eye—the latter to perceive and appreciate more of what is seen, the former to obey more readily and exactly the impulses of the will. Advantage should be taken of the fact that the children come daily under the observation of a quasi-public officer—the school teacher—to secure them protection, to which they are already entitled by law, against hunger, nakedness, dirt, over-work, and other kinds of cruelty and neglect. Children's ailments and diseases should by periodic inspection be detected: the milder ones, such as sores and chilblains, treated on the spot, the more serious removed to the care of parents or hospitals. Diseases of the eye and all maladies that would impair the capacity of

a child to earn its living should in the interest of the community receive prompt attention and the most skilful treatment available. Special schools for children who are crippled, blind, deaf, feeble-minded or otherwise afflicted should be provided at the public cost, from motives, not of mere philanthropy, but of enlightened self-interest. So far as they improve the capacity of such children they lighten the burden on the community.

I make no apology for having dwelt thus long upon the necessity of a sound system of primary instruction: that is the only foundation upon which a national system of advanced education can be built. Without it our efforts and our money will be thrown away. But while primary instruction should be provided for, and even enforced upon, all, advanced instruction is for the few. It is the interest of the commonwealth at large that every boy and girl showing capacities above the average should be caught and given the best opportunities for developing those capacities. It is not its interest to scatter broadcast a huge system of higher instruction for any one who chooses to take advantage of it, however unfit to receive it. Such a course is a waste of public resources. The broadcast education is necessarily of an inferior character, as the expenditure which public opinion will at present sanction is only sufficient to provide education of a really high calibre for those whose ultimate attainments will repay the nation for its outlay on their instruction. It is essential that these few should not belong to one class or caste, but should be selected from the mass of the people, and be really the intellectual *élite* of the rising generation. It must, however, be confessed that the arrangements for selecting these choice scholars to whom it is remunerative for the community to give advanced instruction are most imperfect. No 'capacity-catching machine' has been invented which does not perform its function most imperfectly: it lets go some it ought to keep, and it keeps some it ought to let go. Competitive examination, besides spoiling more or less the education of all the competitors, fails to pick out those capable of the greatest development. It is the smartest, who are also sometimes the shallowest, who succeed. 'Whoever thinks in an examination,' an eminent Cambridge tutor used to say, 'is lost.' Nor is position in class obtained by early progress in learning an infallible guide. The dunce of the school sometimes becomes the profound thinker of later life. Some of the most brilliant geniuses in art and science have only developed in manhood. They would never in their boyhood have gained a county scholarship in a competitive examination.

In primary schools, while minor varieties are admissible, those, for instance, between town and country, the public instruction provided is mainly of one type; but any useful scheme of higher education

must embrace a great variety of methods and courses of instruction. There are roughly at the outset two main divisions of higher education—the one directed to the pursuit of knowledge for its own sake, of which the practical result cannot yet be foreseen, whereby the 'scholar' and the votary of pure science is evolved; the other directed to the acquisition and application of special knowledge by which the craftsman, the designer and the teacher are produced. The former of these is called secondary, the latter technical, education. Both have numerous subdivisions which trend in special directions.

The varieties of secondary education in the former of these main divisions would have to be determined generally by considerations of age. There must be different courses of study for those whose education is to terminate at sixteen, at eighteen and at twenty-two or twenty-three. Within each of these divisions, also, there would be at least two types of instruction, mainly according as the student devoted himself chiefly to literature and language, or to mathematics and science. But a general characteristic of all secondary schools is that their express aim is much more individual than that of the primary school: it is to develop the potential capacity of each individual scholar to the highest point, rather than to give, as does the elementary school, much the same modicum to all. For these reasons it is essential to have small classes, a highly educated staff and methods of instruction very different from those of the primary school. In the formation of character the old secondary schools of Great Britain have held their own with any in the world. In the rapid development of new secondary schools in our cities it is most desirable that this great tradition of British public school life should be introduced and maintained. It is not unscientific to conclude that the special gift of colonizing and administering dependencies, so characteristic of the people of the United Kingdom, is the result of that system of self-government to which every boy in our higher public schools is early initiated. But while we boast of the excellence of our higher schools on the character-forming side of their work, we must frankly admit that there is room for improvement on their intellectual side. Classics and mathematics have engrossed too large a share of attention; science, as part of a general liberal education, has been but recently admitted, and is still imperfectly estimated. Too little time is devoted to it as a school subject; its investigations and its results are misunderstood and undervalued. Tradition in most schools, nearly always literary, alters slowly, and the revolutionary methods of science find all the prejudices of antiquity arrayed against them. Even in scientific studies, lack of time and the obligation to prepare scholars to pass examinations cause too much attention to be paid to theory, and too little to practice, though it is by the latter that the power of original research and of

original application of acquired knowledge is best brought out. The acquisition of modern languages was in bygone generations almost entirely neglected. In many schools the time given to this subject is still inadequate, the method of teaching antiquated, the results unsatisfactory. But the absolute necessity of such knowledge in literature, in science and in commerce is already producing a most salutary reform.

The variety of types of secondary instruction demanded by the various needs and prospects of scholars requires a corresponding variety in the provision of schools. This cannot be settled by a rule-of-three method, as is done in the case of primary instruction. We cannot say that such and such an area being of such a size and of such a population requires so many secondary schools of such a capacity. Account must be taken in every place of the respective demands for respective types and grades of secondary education; and existing provision must be considered.

It must not, however, be forgotten that a national system of education has its drawbacks as well as its advantages. The most fatal danger is the tendency of public instruction to suppress or absorb all other agencies, however long established, however excellent their work, and to substitute one uniform mechanical system, destructive alike to present life and future progress. In our country, where there are public schools of the highest repute carried on for the most part under ancient endowments, private schools of individuals and associations, and universities entirely independent of the Government, there is reasonable hope that with proper care this peril may be escaped. But its existence should never be forgotten. Universal efficiency in all establishments that profess to educate any section of the people may properly be required; but the variety, the individuality and the independence of schools of every sort, primary and secondary, higher and lower, should be jealously guarded. Such attributes once lost can never be restored.

There still remains for our consideration the second division of higher education, viz., the applied or technological side. It is in this branch of education that Great Britain is most behind the rest of the world; and the nation in its efforts to make up the lost ground fails to recognize the fact that real technical instruction (of whatever type) cannot possibly be assimilated by a student unless a proper foundation has been laid previously by a thorough grounding of elementary and secondary instruction. Our efforts at reform are abrupt and disconnected. A panic from time to time sets in as to our backwardness in some particular branch of commerce or industry. There is a sudden rush to supply the need. Classes and schools spring up like mushrooms, which profess to give instruction in the lacking branch of applied

science to scholars who have no elementary knowledge of the particular science, and whose general capacities have never been sufficiently developed. Students are invited to climb the higher rungs of the ladder of learning who have never trod the lower. But science cannot be taught to those who cannot read, nor commerce to those who cannot write. A few elementary lessons in shorthand and bookkeeping will not fit the British people to compete with the commercial enterprise of Germany. Such sudden and random attempts to reform our system of technical education are time and money wasted. There are grades and types in technological instruction, and progress can only be slow. It is useless to accept in the higher branches a student who does not come with a solid foundation on which to build. In such institutions as the Polytechnics at Zurich and Charlottenburg we find the students exclusively drawn from those who have already completed the highest branches of general education; in this country there is hardly a single institution where this could be said of more than a mere fraction of its students. The middle grades of technological instruction suffer from a similar defect. Boys are entered at technical institutions whose only previous instruction has been at elementary schools and evening classes; whose intellectual faculties have not been developed to the requisite point; and who have to be retaught the elements to fit them for the higher instruction. In fact there is no scientific conception of what this kind of instruction is to accomplish and of its proper and necessary basis of general education.

Yet this is just the division of higher education in which public authority finds a field for its operations practically unoccupied. There are no ancient institutions which there is risk of supplanting. The variety of the subject itself is such that there is little danger of sinking into a uniform and mechanical system. What is required is first a scientific, well-thought-out plan and then its prompt and effective execution. A proper provision of the various grades and types of technological instruction should be organized in every place. The aim of each institution should be clear; and the intellectual equipment essential for admission to each should be laid down and enforced. The principles of true economy, from the national point of view, must not be lost sight of. Provision can only be made (since it must be of the highest type to be of the slightest use) for those really qualified to profit by it to the point of benefiting the community. Evening classes with no standard for admission and no test of efficiency may be valuable from a social point of view as providing innocent occupation and amusement, but they are doing little to raise the technical capacity of the nation. So far from 'developing a popular demand for higher instruction' they may be preventing its proper growth by perpetuating the popular misconception of what real technical instruction is, and

of the sacrifices we must make if our people are to compete on equal terms with other nations in the commerce of the world. The progress made under such a system would at first be slow; the number of students would be few until improvements in our systems of primary and secondary instruction afforded more abundant material on which to work; but our foundation would be on a rock, and every addition we were able to make would be permanent, and contribute to the final completion of the edifice.

It is the special function of the British Association to inculcate 'a scientific view of things' in every department of life. There is nothing in which scientific conception is at the present moment more urgently required than in national education; and there is this peculiar difficulty in the problem, that any attempt to construct a national system inevitably arouses burning controversies, economical, religious and political. It is only a society like this, with an established philosophical character, that can afford to reduce popular cries about education (which ignore what education really is, and perpetuate the absurdity that it consists in attending classes, passing examinations and obtaining certificates) to their true proportions. If this Association could succeed in establishing in the minds of the people a scientific conception of a national education system, such as has already been evolved by most of the nations of Europe, the States of America, and our own colonies, it would have rendered a service of inestimable value to the British nation.

THE EVOLUTION OF THE HUMAN INTELLECT.

By Professor EDWARD L. THORNDIKE,
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TO the intelligent man with an interest in human nature it must often appear strange that so much of the energy of the scientific world has been spent on the study of the body and so little on the study of the mind. 'The greatest thing in man is mind,' he might say, 'yet the least studied.' Especially remarkable seems the rarity of efforts to trace the evolution of the human intellect from that of the lower animals. Since Darwin's discovery, the beasts of the field, the fowl of the air and the fish of the sea have been examined with infinite pains by hundreds of workers in the effort to trace our physical genealogy, and with consummate success; yet few and far between have been the efforts to find the origins of intellect and trace its progress up to human faculty. And none of them has achieved any secure success.

It may be premature to try again, but a somewhat extended series of studies of the intelligent behavior of fishes, reptiles, birds and mammals, including the monkeys, which it has been my lot to carry out during the last five years, has brought results which seem to throw light on the problem and to suggest its solution.

Experiments have been made on fishes, reptiles, birds and various mammals, notably dogs, cats, mice and monkeys, to see how they learned to do certain simple things in order to get food. All these animals manifest fundamentally the same sort of intellectual life. Their learning is after the same general type. What that type is can be seen best from a concrete instance. A monkey was kept in a large cage. Into the cage was put a box, the door of which was held closed by a wire fastened to a nail which was inserted in a hole in the top of the box. If the nail was pulled up out of the hole the door could be pulled open. In this box was a piece of banana. The monkey, attracted by the new object, came down from the top of the cage and fussed over the box. He pulled at the wire, at the door and at the bars in the front of the box. He pushed the box about and tipped it up and down. He played with the nail and finally pulled it out. When he happened to pull the door again it of course opened. He reached in and got the food inside. It had taken him 36 minutes to get in. Another piece of food being put in and the door closed the occurrences of the first trial were repeated, but there was less of the profitless pulling and tipping. He got in this time in 2 minutes and 20 seconds. With repeated trials

the animal finally came to drop entirely the profitless acts and to take the nail out and open the door as soon as the box was put in his cage. He had, we should say, learned to get in.

The process involved in the learning was evidently a process of selection. The animal is confronted by a state of affairs or, as we may call it, a 'situation.' He reacts in the way that he is moved by his innate nature or previous training to do, by a number of acts. These acts include the particular act that is appropriate and he succeeds. In later trials the impulse to this one act is more and more stamped in, this one act is more and more associated with that situation, is selected from amongst the others by reason of the pleasure it brings the animal. The profitless acts are stamped out; the impulses to perform them in that situation are weakened by reason of the positive discomfort or the absence of pleasure resulting from them. So the animal finally performs in that situation only the fitting act.

Here we have the simplest and at the same time the most widespread sort of intellect or learning in the world. There is no reasoning, no process of inference or comparison; there is no thinking about things, no putting two and two together; there are no ideas—the animal does not think of the box or of the food or of the act he is to perform. He simply comes after the learning to feel like doing a certain thing under certain circumstances which before the learning he did not feel like doing. Human beings are accustomed to think of intellect as the power of having and controlling ideas and of ability to learn as synonymous with ability to have ideas. But learning by having ideas is really one of the rare and isolated events in nature. There may be a few scattered ideas possessed by the higher animals, but the common form of intelligence with them, their habitual method of learning, is not by the acquisition of ideas, but by the selection of impulses.

Indeed this same type of learning is found in man. When we learn to drive or play tennis or billiards, when we learn to tell the price of tea by tasting it or to strike a certain note exactly with the voice, we do not learn in the main by virtue of any ideas that are explained to us, by any inferences that we reason out. We learn by the gradual selection of the appropriate act or judgment, by its association with the circumstances or situation requiring it in just the way that the animals do.

From the lowest animals of which we can affirm intelligence up to man this type of intellect is found. With it there are in the mammals obscure traces of the ideas which come in the mental life of man to outweigh and hide it. But it is the basal fact. As we follow the development of animals in time we find the capacity to select impulses growing. We find the associations thus made between situation and act growing in number, being formed more quickly, lasting longer and

becoming more complex and more delicate. The fish can learn to go to certain places, to take certain paths, to bite at certain things and refuse others, but not much more. It is an arduous proceeding for him to learn to get out of a small pen by swimming up through a hole in a screen. The monkey can learn to do all sorts of things. It is a comparatively short and easy task for him to learn to get into a box by unhooking a hook, pushing a bar around and pulling out a plug. He learns quickly to climb down to a certain place when he sees a letter T on a card and to stay still when he sees a K. He performs the proper acts nearly as well after 50 days as he did when they were fresh in his mind.

This growth in the number, speed of formation, permanence, delicacy and complexity of associations possible for an animal reaches its acme in the case of man. Even if we leave out of question the power of reasoning, the possession of a multitude of ideas and abstractions and the power of control over impulses, purposive action, man is still the intellectual leader of the animal kingdom by virtue of the superior development in him of the power of forming associations between situations or sense impressions and acts, by virtue of the degree to which the mere learning by selection possessed by all intelligent animals has advanced. In man the type of intellect common to the animal kingdom finds its fullest development, and with it is combined the hitherto non-existent power of thinking about things and rationally directing action in accord with thought.

Indeed it may be that this very reason, self-consciousness and self-control which seem to sever human intellect so sharply from that of all other animals are really but secondary results of the tremendous increase in the number, delicacy and complexity of associations which the human animal can form. It may be that the evolution of intellect has no breaks, that its progress is continuous from its first appearance to its present condition in adult civilized human beings. If we could prove that what we call ideational life and reasoning were not new and unexplainable species of intellectual life but only the natural consequences of an increase in the number, delicacy and complexity of associations of the general animal sort, we should have made out an evolution of mind comparable to the evolution of living forms.

In 1890 William James wrote, "The more sincerely one seeks to trace the actual course of psycho-genesis, the steps by which as a race we may have come by the peculiar mental attributes which we possess, the more clearly one perceives 'the slowly gathering twilight close in utter dark.'" Can we perhaps prove him a false prophet? Let us first see if there be any evidence that makes it probable that in some way or another the mere extension of the animal type of intellect has produced the human sort. If we do let us proceed to seek a possible

account of *how* this might have happened, and finally to examine any evidence that shows this possible 'how' to have been the real way in which human reason has evolved.

It has already been shown that in the animal kingdom there is, as we pass from the early vertebrates down to man, a progress in the evolution of the general associative process which practically equals animal intellect, that this progress continues as we pass from the monkeys to man. Such a progress is a real fact; it does exist as a possible *vera causa;* it is thus at all events better than some imaginary cause of the origin of human intellect, the very existence of which is in doubt. In a similar manner we know that the cell structures which compose the brain and the connections between which are the physiological parallel of the associations animals form show as we pass down through the vertebrate series an evolution along lines of increased delicacy and complexity. That an animal associates a certain act with a certain felt situation means that he forms or strengthens connections between certain cells. The increase in the number, delicacy and complexity of cell structures is thus the basis for an increase in the number, delicacy and complexity of associations. Now the evolution noted in cell structures affects man as well as the other vertebrates. He stands at the head of the scale in that respect as well. May not this obvious supremacy in the animal type of intellect and in the adaptation of his brain to it be at the bottom of his supremacy in being the sole possessor of reasoning?

This question becomes more pressing if we realize that we must have some sort of brain correlate for ideational life and reasoning. Some sort of difference in processes in the brain must be at the basis of the mental differences between man and the lower animals, we should all admit. And it would seem wise to look for that difference amongst differences which really do or at least may exist. Now the most likely brain difference between man and the lower animals for our purpose, to my mind indeed the only likely one, is just this difference in the fineness of organization of the cell structures. If we could show with any degree of probability how it might account for the presence of ideas and of reasoning we should at least have the satisfaction of dealing with a cause actually known to exist.

The next important fact is that the intellect of the infant six months to a year old is of the animal sort, that ideational and reasoning life is not present in his case, that the only obvious intellectual difference between him and a monkey is in the quantity and quality of the associations formed. In the evolution of the infant's mind to its adult condition we have the actual transition within an individual from the animal to the human type of intellect. If we look at the infant and ask what is in him to make in the future a thinker and

reasoner, we must answer either by invoking some mysterious capacity, the presence of which we cannot demonstrate, or by taking the difference we actually do find. That is the difference in the quality and quantity of associations of the animal sort. Even if we could never see how it came to cause the future intellectual life, it would seem wiser to believe that it did than to resort to faith in mysteries. Surely there is enough evidence to make it worth while to ask our second question, 'How might this difference cause the life of ideas and reasoning?'

To answer this question fully would involve a most intricate treatment of the whole intellectual life of man, a treatment which cannot be attempted without reliance on technical terms and psychological formulas. A fairly comprehensible account of the general features of such an answer can however be given. The essential thing about the thinking of the animals is that they feel things in gross. The kitten that learned to respond differently to the signals 'I must feed those cats' and 'I will not feed them,' felt each signal as a vague total including the tone, the movements of my head, etc. It did not have an idea of the sound of *I,* another of the sound of *must,* another of the sound of *feed,* etc. It did not turn the complex impression into a lot of elements, but felt it, as I have said, in gross. The dog that learned to get out of a box by pulling a loop of wire did not feel the parts of the box separately, the loop as a definite circle of a certain size, did not feel his act as a sum of certain particular movements. The monkey that learned to know the letter K from the letter Y did not feel the separate lines of the letter, have definite ideas of the parts. He just felt one way when he saw one total impression and another way when he saw another.

Strictly human thinking on the contrary has for its essential characteristic the breaking up of gross total situations into a number of particular feelings. When in the presence of ten jumping tigers, we not only feel like running, but also feel the number of the tigers, their color, their size, etc. When instead of merely associating some act with some situation in the animal way, we think the situation out, we have a number of particular feelings of its elements. In some cases it is true we remain restricted to the animal sort of feelings. The sense impressions of suffocation, of the feeling of a new style of clothes, of the pressure of 10 feet of water above us, of malaise, of nausea and such like, remain for most of us vague total feelings to which we react and which we feel most acutely, but which do not take the form of definite ideas that we can isolate or combine or compare. Such feelings we say are not parts of our real intellectual life. They *are* parts of our intellectual life if we mean by it the mental life concerned in learning, but they are not if we mean by it the life of reasoning.

Can we now see how the vague gross feelings of the animal sort might turn into the well-defined particular ideas of the human sort, by the aid of a multitude of delicate associations?

It seems to be a general law of mind that any mental element which occurs with a number of different mental elements, appears that is in a number of different combinations, tends to thereby acquire an independent life of its own. We show children six lines, six dots, six peas, six pieces of paper, etc., and thus create the definite feeling of sixness. Out of the gross feelings of a certain number of lines, of dots, etc., we evolve the definite elementary feeling of sixness by making the 'six' aspect of the situations appear in a number of different connections. We learn to feel whiteness as a definite idea by seeing white paper, white cloth, white eggs, white plates, etc., etc. We learn to feel the meaning of *but* or *in* or *notwithstanding* by feeling the meaning of a number of total phrases containing each of them. Now in this general law by which different associates for the same elementary process elevate it out of its position as an undifferentiated fragment of a gross total feeling, we have, I think, the manner in which the vague feelings of the nine-months-old infant become the definite ideas of the five-year-old boy, the manner in which in the race the animal mind has evolved into the human, and the explanation of the service performed by the increase in the delicacy of structure of the human brain and the consequent increase in the number of associations.

The bottle to the six-months-old infant is a vague sense impression which the infant does not think about or indeed in the common meanings of the words perceive or remember or imagine. Its presence does not arouse ideas, but action. It is not to him a thing so big, or so shaped, or so heavy, but is just a vaguely sizable thing to be reached for, grabbed and sucked. Like the lower animals, with the exception that as he grows a little older he reacts in very many more ways, the child feels things in gross in a way to lead to direct reactions. Vague sense impressions and impulses make up his mental life. The bottle, which to a dog would be a thing to smell at and paw, to a kitten a thing to smell at and perhaps worry, is to the child a little later a thing to grab and suck and turn over and drop and pick up and pull at and finger and rub against its toes and so on. The sight of the bottle thus becomes associated with a lot of different reactions, and thus by our general law tends to gain a position independent of any of them, to evolve from the condition of being a portion of the cycles see-grab, see-drop, see-turn over, etc., to the condition of being a definite idea.

The increased delicacy and complexity of the cell structures in the human brain gives the possibility of very small parts of the brain processes forming different connections, allows the brain to work in

very great detail, provides processes ready to be turned into definite ideas. The great number of associations which the human being forms furnish the means by which this last event is consummated. The infant's vague feelings of total situations are by virtue of the detailed working of his brain all ready to split up into parts, and his general activity and curiosity provide the multitude of different connections which allow them to do so. The dog on the other hand has few or no ideas because his brain acts in coarse fashion and because there are few connections with each single process.

When once the mind begins to function by having definite ideas all the phenomena of reasoning soon appear. The transition from one idea to another is the feeling of their relationship, of similarity or difference or whatever it may be. As soon as we find any words or other symbols to express such a feeling, or to express our idea of an action or condition, we have explicit judgments. Observation of any child will show us that the mind cannot rest in a condition where it has a large body of ideas without comparing them and thinking about them. The ideas carry within them the forces that make abstractions, feelings of similarity, judgments and the other characteristics of reasoning.

In children two and three years of age we find all these elements of reasoning present and functioning. The product of children's reasoning is often irrational but the processes are all there. The following instances from a collection of children's sayings by Mr. H. W. Brown show children making inductions and deductions after the same general fashion as adults:

(2 yrs.) T. pulled the hairs on his father's wrist. Father. "Don't T., you hurt papa!" T. "It didn't hurt grandpa."

(2 yrs. 5 mos.) M. said, "Gracie can't walk, she wears little bits of shoes; if she had mine she could walk. When I get some new ones, I'm going to give her these, so she can walk."

(3 yrs.) W. likes to play with oil paints. Two days ago my father told W. he must not touch the paints any more, for he was too small. This morning W. said, "When my papa is a very old man, and when I am a big man and don't need any papa, then I can paint, can't I, mamma?"

(3 yrs.) G.'s aunt gave him ten cents. G. went out, but soon came back saying, "Mamma, we will be rich now." "Why so, G?" "Because I planted my ten cents, and we will have lots of ten cents growing."

(3 yrs.) B. climbed up into a large express wagon, and would not get out. I helped him out, and it was not a minute before he was back in the wagon. I said, "B., how are you going to get out of there now?" He replied, "I can stay here till it gets little, and then I can get out my own self."

(3 yrs.) F. is not allowed to go to the table to eat unless she has her face and hands washed and her hair combed. The other day she went to a lady visiting at her house and said, "Please wash my face and hands and comb my hair; I am very hungry."

(3 yrs.) If C. is told not to touch a certain thing, that it will bite him,

he always asks if it has a mouth. The other day he was examining a plant, to see if it had a mouth. He was told not to break it, and he said, "Oh, it won't bite, because I can't find any mouth."

Nowhere in the animal kingdom do we find the psychological elements of reasoning save where there is a mental life made up of the definite feelings which I have called 'ideas,' but they spring up like magic as soon as we get in a child a body of such ideas. If we have traced satisfactorily the evolution of a life of ideas from the animal life of vague sense impressions and impulses we may be reasonably sure that no difficulty awaits us in following the life of ideas in its course from the chaotic dream of early childhood to the logical world-view of the adult scientist.

In a very short time we have come a long way, from the simple learning of the minnow or chick to the science and logic of man. The general frame of mind which one acquires from the study of animal behavior and of the mental development of young children makes our hypothesis seem vital and probable. If the facts did eventually corroborate it we should have an eminently simple genesis of human faculty, for we could put together the gist of our contention in a few words. We should say:

"The function of intellect is to provide a means of modifying our reactions to the circumstances of life so that we may secure pleasure, the symptom of welfare. Its general law is that when in a certain situation an animal acts so that pleasure results, that act is selected from all those performed and associated with that situation so that when the situation recurs the act will be more likely to follow than it was before, that on the contrary the acts which when performed in a certain situation have brought discomfort tend to be dissociated from that situation. The intellectual evolution of the race consists in an increase in the number, delicacy, complexity, permanence and speed of formation of such associations. In man this increase reaches such a point that an apparently new type of mind results, which conceals the real continuity of the process. This mental evolution parallels the evolution of the cell structures of the brain from fewer and simpler and grosser to many and complex and delicate."

Nowhere more truly than in his mental capacities is man a part of nature. His instincts, that is his inborn tendencies to feel and act in certain ways, show throughout marks of kinship with the lower animals, especially with our nearest relatives physically, the monkeys. His sense powers show no new creation. His intellect we have seen to be a simple though extended variation from the general animal sort. This again is presaged by the similar variation in the case of the monkeys. Amongst the minds of animals that of man leads, not as a demigod from another planet, but as a king from the same race.

THE ORIGIN OF SEX IN PLANTS.

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ZOOLOGISTS have held various views as to the origin of sex in animals, but the subject is confessedly speculative. They have very little data bearing upon the problem—the gap between the Protozoa and the Metazoa is so immense and characterized by such a paucity of intermediate types. We pass directly from relatively simple conjugation among unicellular forms to the complicated conditions in higher animals, where the sexual elements have reached a very high state of specialization.

Botany is very much more fortunate in this respect. It is not difficult to understand the evolution of multicellular plants from the unicellular, and we have a great deal of evidence that bears on the origin and differentiation of sex. Greater interest is added to this subject because we have reason to believe that sex has arisen in a number of divergent groups by identical processes but without relation to one another, so that similar complex results have been worked out independently.

We shall deal entirely with that large group of the lower plants known as the algae which includes all the plants below the liverworts and mosses with the exception of the fungi. One need study the algæ but slightly to realize that they are a very diverse assemblage of forms comprising many lines of ascent, some of which are marked out clearly, but many of them mere fragments and remnants of former series that have been broken up by the extinction of ancestral types.

There are certain groups of algae well known to all students of botany that have no place in the present discussion. Such for example are the Conjugales comprising types such as Spirogyra, Zygnema, the desmids, and again, the diatoms. However valuable these forms may be for certain laboratory studies, they should never be cited as typical illustrations of sexual processes among the lower plants. They are rather extraordinarily specialized groups and have developed peculiarities of a high order. Again, there are numbers of groups complex in their organization, whose relationship to other forms is so remote that we must place them quite apart by themselves. Such for example are the stoneworts (Charales), the red algae (Rhodophyceae) and some

forms of the brown algae (Phaeophyceae). These groups give us no data on the problems that we are to consider.

There is left for us a numerous and varied array of algae, representing several lines of ascent, all tending to diverge from one another. But these forms have some important points in common, particularly as concerns certain events in their life histories. There is immense variety in the form of the plant body which ranges from a single cell to structures with stalks and leaf-like organs. There are likewise exhibited many degrees of sexual development, from a few forms which actually appear to illustrate the dawning of sex through various intermediate stages to many types in which the sexual elements have become highly specialized. The story of the differentiation of sex, that is, the evolution of the egg and sperm from the primitive sexual elements, is most interesting, but would require extended treatment. It must be left for some future paper. Our problem is to understand how the primitive sexual elements arose.

Almost all the algae in the groups referred to in the paragraph above have one phase in their life histories in common. They usually present a period, although sometimes very short, when the protoplasm of the cells is in the form of free-swimming elements. These are called zoospores or swarm-spores and they are commonly little pear-shaped bodies, the pointed ends bearing 2 or perhaps 4 delicate hair-like organs, called cilia, whose vibrations give the zoospores their rapid movement. A glance at the illustrations will show the form of these motile cells.

Zoospores are likely to be produced in greatest quantity at certain seasons or under particular conditions of light or temperature, and their purpose is plainly the rapid propagation of the species. But there is a deep significance in their general conformity to a certain type of structure and their almost universal presence in the groups that we are considering. In a certain sense the zoospore represents a return on the part of these algae to primitive ancestral conditions.

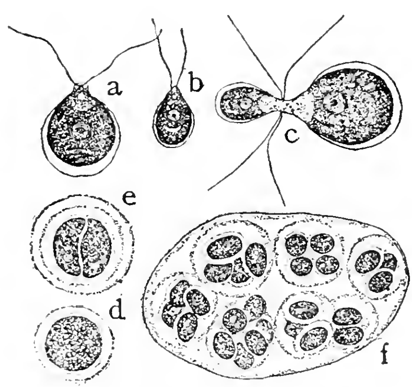

Fig. 1. Stages in the Life History of Chlamydomonas. *a*, Vegetative Cell. *b*, Small Gamete. *c*, Conjugation of Gametes. *d*, Sexually Formed Spore. *e*, First Division of Spore. *f*, Quiescent Condition, Cells Multiplying by Division. (After Goroschankin.)

There are many unicellular algae that pass a large part, perhaps the greater part, of their lives as motile cells with a structure essentially the same as

zoospores. These lowly types of the Protococcales are certainly most nearly related to the parent forms of all the higher algae. The principal stages in the life history of such a type (Chlamydomonas) are illustrated in Figure 1. The free-swimming cell is shown in *a* and *b*. In *c* we have the conjugation of two individuals which gives a sexually formed spore such as appears in *d*. *e* and *f* present a quiescent condition when the cells multiply for a short time by fission.

The evolution of the algae has led for the most part to the development and long continuance of such phases of the life history as are stationary, and from these the filamentous, membranous and otherwise differentiated plant bodies have arisen. Finally the motile stage became so shortened as to be only a method of reproduction on the part of the plant and is passed over very quickly.

The zoospore then takes on new interest when one contemplates its relation to the past, realizing that it represents conditions of a remote period when the algae were much simpler than they are now and passed the greater part of their lives in a motile condition. It is not likely that the first algal types were motile, for the lowest group of all, the Cyanophyceae or blue-green algae, presents forms whose cells are always stationary, reproducing by simple fission.

But above the lower stretches of the algae, the zoospore appears with great regularity and usually conspicuously in the life history. There are certain types (unicellular Volvocaceae), whose life histories are mostly or entirely alternations of motile conditions and quiescent states when the cells come to rest, lose their cilia and remain motionless for many days. Such resting cells are well known to students of the lower algae, and it is an interesting fact that they may pass quickly and readily back to the motile form. Indeed there is every reason to believe that the one state or the other is largely determined by the physical environment of the organism. Recent studies by Livingston have shown for one type (Stigeoclonium) that zoospores immediately follow the transfer of cells in a resting condition from a certain solution of salts to a weaker solution, and this is an excellent illustration of the sort of factors that influence the alga.

In our discussion of the problem of the origin of sex we are to deal chiefly with forms whose motile conditions are so shortened as to be manifestly largely or wholly reproductive in their purposes. The plants are stationary, but at times and under certain conditions zoospores are produced in great numbers. These, after a brief existence as free-swimming cells, settle down and give rise to a new stationary plant body usually like the parent.

Zoospores or swarm spores are wonderfully alike in structure in the algae that are most closely related to one another. The prevailing type among the green algae (Chlorophyceae) is a pear-shaped cell with 2

or frequently 4 cilia at the pointed end. The illustrations show these and other characters clearly. A portion of the protoplasm is differentiated as a green body (chloroplast), which only partially fills the rounded end of the zoospore, leaving the rest of the cell quite clear. Sometimes the chloroplast contains a central body called the pyrenoid, which is associated with the starch-forming activities of the chloroplast. This structure must not be confused with the nucleus of the cell, the latter being almost always invisible in the living zoospore. Finally, one may always expect to find in the colorless pointed end, near the cilia, a small bright red body called the pigment spot. The pigment spot is generally believed to have a relation to the sensitiveness displayed by zoospores towards light, not in any sense, however, as an organ of vision, as might be judged by the unfortunate term 'eye-spot' that is sometimes applied to it.

Such is the structure of the zoospores. Now let us consider their habits. As we have said before, several are likely to be developed in a single cell, but there is no rule as to number. Sometimes the entire contents of a cell will slip out as a single zoospore, but more frequently 8, 16 or 32 will be formed, a variable number even in the same plant, and in certain cases the parent cell will give rise to hundreds. The zoospores escape from the mother cell or sporange usually through some opening in the wall and immediately swim off. They may be developed so numerously that the water is actually colored greenish and the field of the microscope shows hundreds of these organisms moving rapidly in various directions. Such appearances have given them the appropriate name of swarm-spores. The swarming of zoospores is best shown under certain conditions of illumination. The zoospores are very sensitive to light and usually arrange themselves with reference to its source so that the long axes are parallel with the incoming rays. If a vessel of water be placed so that the light rays come from one direction, as from a window, the zoospores will move in parallel lines towards or away from the source of the illumination. They will thus collect in clouds in various parts of the vessel, the exact position being somewhat modified by the currents of water that slowly circulate through every brightly illuminated vessel.

Generally speaking the swarm-spores that one is most likely to see will be asexual. Their activities cease after a few hours or perhaps minutes and they then attach themselves in some suitable position, germinate and develop young plants called sporelings. Sporelings of the alga, Ulothrix, are shown in Figure 2, *d*, they having developed from a zoospore like *c*.

But frequently and under conditions that have been in part determined swarm-spores will behave quite differently. They will swim at first very actively, approaching one another and then darting away,

but finally gathering in small groups and sorting themselves in pairs. The elements in such a pair begin to fuse together; the process is called conjugation and represents the simplest form of sexuality. The two sexual cells are called gametes, but they are nothing more than zoospores so constituted that they must fuse with one another in order to live.

The gametes show their relationship to zoospores in various ways and there is no doubt that they arose from the latter. In the first place they have the same general structure and are developed in the same sorts of cells on the mother plant. But the most important evidence of affinity is exhibited by certain gametes that are so much like zoospores that they will sometimes settle down and germinate without conjugation. This means that their sexual characters are not strongly enough developed to overcome the vegetative tendencies of their parents the asexual zoospores. However, the sporelings that come from these abortive or perhaps parthenogenetic gametes are weaker than the products of the ordinary or normal zoosopores and sometimes never reach full development. As may be guessed, this curious intermediate condition between the zoospore and gamete furnishes a most important clue to the fundamental distinctions that separate the one from the other. These differences are evidently physiological rather than morphological in character.

It is only recently that botanists have in part understood and attempted to define precisely the conditions that determine the development on the one hand of zoospores and on the other of gametes. In a general way it has been believed for a long time that the problem was a physiological one and that various environmental conditions of season, temperature or light were responsible for the results. But in the past ten years there have been numerous studies, on various types of the lower plants, attempting to establish as exactly as possible the chemical and physical factors at work. In this field of research the botanist, Klebs, has been especially active, and he, above all others, deserves the credit of developing certain experimental methods of attack. These have yielded important results and justify the belief that we may in the future obtain much precise knowledge.

Klebs treats the forms to as many well-defined conditions as he can devise, various as to the food, the osmotic properties of the water, the light and the temperature. The results have been very remarkable considering the difficulties of the problems. We can not do better than to follow his studies on one or two forms to illustrate the possibilities of investigations in this difficult field.

His studies on Ulothrix are interesting. This is a lowly type of unbranched filamentous alga common in both fresh and salt water. The zoospores (Figure 2, *b*) are formed in varying numbers, but usually

4 or 8 in a cell. They are relatively large structures with 4 cilia and have the appearance shown in Figure 2, *c*. These 4-ciliate zoospores are never sexual and they develop new Ulothrix filaments like their parent. This simple method of reproduction may be continued for

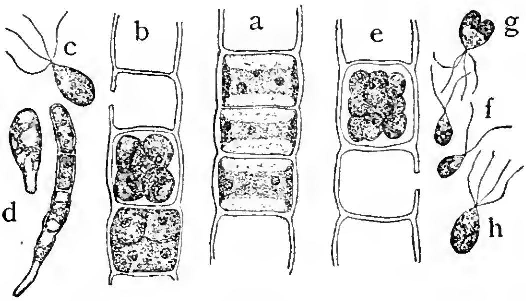

FIG. 2. ULOTHRIX. *a*, VEGETATIVE FILAMENT. *b*, DEVELOPMENT OF ASEXUAL ZOOSPORES. *c*, ZOOSPORE. *d*, SPORELINGS. *e*, CELL CONTAINING GAMETES. *f*, GAMETES. *g*, CONJUGATION OF GAMETES. *h*, SEXUALLY FORMED SPORE.

many months, but at times the conditions are such that another form of swarm-spore appears. These elements are much smaller than the usual zoospores, are developed more numerously in the mother cell and have 2 cilia as is shown in Figure 2, *e, f*. They are gametes and as a rule fuse readily with one another in pairs. The free-swimming gametes are shown in Figure 2, *f*, and two stages in the conjugation appear in *g* and *h*. If conjugation does not take place, the gametes settle down and in certain instances have been observed slowly germinating; but they develop feeble plants.

Now what are the causes that make the plant produce asexual zoospores on the one hand and gametes on the other? Are they deeply seated in the protoplasm of Ulothrix? In the first place there is no rule or rhythm in the appearance of zoospores or gametes, no time when conditions within the plant demand their development. And again, structurally, there is no hard and fast line between the zoospore and gamete; on the contrary, there are gradual transitions between these two forms of swarm spores. The problem thus resolves itself into an inquiry as to the precise environmental influences, the chemical and physical factors affecting the Ulothrix filament, whether they are actually able to make the plant form zoospores or not according to certain conditions. The habits of Ulothrix show us clearly that there are such factors, but the adjustments are so delicate that, apart from a very clear relation to temperature and the character of the salts in solution, it has not been possible to formulate them with exactness.

But other studies of Klebs, on forms that lend themselves more readily to cultivation than Ulothrix, have given some very definite results. Hydrodictyon, the water-net, is an alga that may be cultivated

with great ease in the laboratory. This plant is a great cell colony, involving usually thousands of elements which are joined to one another to form a net of polygonal meshes. A portion of such a plant is shown in Figure 3, *a*. These cells after they have reached a certain age produce zoospores that may be either asexual or sexual (gametes). The gametes are smaller and are produced much more numerously than

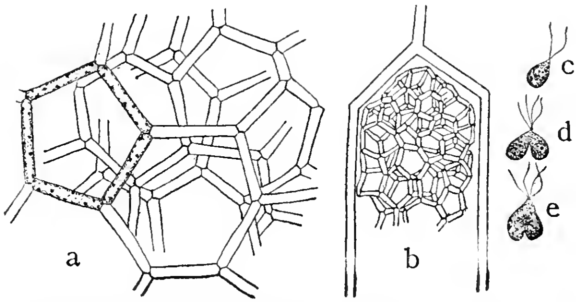

FIG. 3. HYDRODICTYON. *a*, PORTION OF NET. *b*, END OF CELL SHOWING YOUNG NET IN ITS INTERIOR. *c*, GAMETE. *d*, *e*, CONJUGATION OF GAMETES.

the asexual elements. They escape from the mother-cell and after swarming in the water conjugate in pairs (see Figure 3, *c*, *d*, *e*). The asexual swarm-spores have the peculiarity of never leaving the mother cell. They swim around in the cavity bounded by the cell wall and shortly come to rest, arranging themselves to form a new net entirely within the parent cell. Thus by their habits one may readily distinguish the asexual zoospores and gametes of Hydrodictyon.

Now let us summarize the factors that will make Hydrodictyon form asexual zoospores at one time and gametes at another. The water-net grows luxuriantly in a culture solution containing a number of inorganic salts. If plants are removed from such a culture solution and placed in fresh water they will develop zoospores in 24 hours. The process takes place most rapidly if the temperature is slightly above the normal; indeed merely warming the water in which plants are living will frequently induce the production of zoospores. Plants refuse to form zoospores at a temperature as low as 8° C. but if such a culture be raised to the warmth of 16° or 20° the process is immediately resumed. Gametes are produced under very different conditions from those stated above. They demand organic food. Cultures of Hydrodictyon in a solution of cane sugar will almost certainly yield gametes after several days.

It frequently happens that the nets of Hydrodictyon will exhibit a well-defined tendency or preference to form either gametes or zoospores. Such a habit may be quite thoroughly broken by cultivating a plant under proper surroundings. Gamete-forming nets will shortly

produce zoospores if grown in solution of inorganic salts and in bright sunlight. Nets with strong inclinations to form zoospores can be made to produce gametes by cultivating in a sugar solution in subdued light or darkness. Plants that have no special inclination to form either zoospores or gametes may be decided one way or the other by the illumination, bright light producing zoospores and darkness gametes. It is also fair to say that sometimes the tendency to form zoospores is so strong that a plant will not yield for several generations to the conditions that generally bring about the immediate production of gametes.

Let these studies on Hydrodictyon and Ulothrix stand as illustrations of the kind of evidence presented in varying degrees by many algae and fungi and constantly increasing as investigations in physiology proceed. The general trend seems unmistakable. We may feel sure that sexual elements, gametes, have arisen from asexual reproductive cells with an immediate relation to and probably because of certain environmental factors. In a general way these factors are known to be light, temperature, osmotic pressure and, most important of all, the chemical nature of the environment with especial reference to the kinds of foods.

What was the change that came over the asexual reproductive cell when it took on the stamp of sex? The differences are best measured in the possibilities of the two elements. The asexual zoospores may quickly and readily produce a new individual. The gamete, generally speaking, must fuse with its kind or else die. We have seen that primitive gametes may germinate without conjugation but the resulting plants in the cases best known are weaker than normal individuals. We also know that the lower stretches of the plant kingdom furnish abundant illustrations of parthenogenesis, that is, the power of an egg cell to develop without fertilization. These exceptions, however, strengthen the evidence that the essential differences between gametes and asexual zoospores are qualities lacking in the former, and especially the ability to continue and sustain the mechanism demanded by vital processes.

With conjugation all is changed, and the sexually formed spore has the qualities lacking in the two gametes from which it arose. The protoplasm is in a sense rejuvenated and with the stimulus comes sooner or later an expression frequently more vigorous than that of the asexual spore.

The most striking conjecture on the significance and origin of sex has been presented under the name 'autophagy.' It is a very simple hypothesis. However, its simplicity is its greatest danger and will probably be its complete undoing, for enough is known to indicate that the factors and conditions that produce the sexual act are im-

mensely varied and complex. Autophagy explains the sexual act as a process by which sexual cells mutually devour one another. Each is fed to the other and by mutually contributing their substance both make possible the energy exhibited by the fusion cell.

Autophagy conceives the sexual cell (gamete) as one that lacks the energy of its progenitor, the asexual element. It is a cell reduced and starved. Ordinarily its vitality is at such a low ebb that further development is impossible. Sometimes it is not so far gone but that a favorable environment will induce parthenogenetic growth. The sexual cell may be brought back to virile activity with power to propagate the race, if supplied with the necessary energy. And the simplest method of attaining this end, according to autophagy, is the cooperative union of these weakened elements, a mutual feast, which revives the worn-out protoplasm and enables the fusion products to make a fresh start.

The hypothesis of autophagy may be attacked from several points, and becomes very unsatisfactory when so examined. It is crude and entirely insufficient to cover the subtle phenomena that it attempts to handle. The cause of the fusion of gametes involves problems of chemistry and physics which can only be investigated by methods of extreme delicacy and precision. One may see at a glance that conjugation is not the same as the actual feeding of one unicellular organism upon another. In such a case, which might be illustrated with many Protozoa, the captive form is destroyed and its dead substance is then worked over through elaborate changes into the protoplasm of the living cell. In the conjugation of sexual cells, the two masses of protoplasm fuse and mingle and perhaps the most significant feature of the process is the union of the two sexual nuclei.

As a matter of fact, sexual cells are, generally speaking, well nourished, and in all higher organisms the egg is specially provided with food, far above the amount ordinarily present in cells. The unfertilized egg does not lack food, but is unable to command the necessary energy or, if such be present, it is tied up in some form that cannot be used. The importance of the latter condition is indicated by the investigations of Dr. Loeb, who found that a slight increase in the density of sea-water will induce the immediate development of the unfertilized eggs of sea urchins, star fishes and a certain worm. In the earlier experiments, salts of magnesium and potassium were added to the sea-water, but later studies have shown that sugar induces similar parthenogenetic development. It is suggested that merely the withdrawal of water from the egg by osmosis is sufficient to cause its development without sexual intervention. And it may be supposed that normally the sperm brings to the egg substances that excite such conditions within the egg that water is given off. But we are far from

understanding how such results are accomplished in nature or what other factors may be concerned.

It is certainly plain that the conditions surrounding sexual processes are immensely complex, and as yet we only know them in part and for a very few organisms. There is every reason to expect that investigation will so add to these that the subject will consist of very complicated problems in physics and chemistry. But it is something to know that important factors exist outside of the organism controlling in great part the sexual phase, and that some of them are so simple as light, temperature and osmotic pressure. Much is gained for biology in the understanding that sexual elements have arisen from asexual reproductive cells under the stress of environmental influences; that sexuality is not inherent in life although presented in almost all higher organisms, and that, however complicated the extreme conditions may be, they have arisen through a process of gradual evolution.

In another paper I shall hope to show the steps by which the highly differentiated egg and sperm in various groups of plants developed from the similar gametes presented at the dawning of sex. As stated in the beginning of this paper, the topic is a chapter in itself and well deserves separate treatment.

THE FISHES OF JAPAN.

WITH OBSERVATIONS ON THE DISTRIBUTION OF FISHES.

By DAVID STARR JORDAN,
PRESIDENT OF LELAND STANFORD JUNIOR UNIVERSITY.

THE islands of Japan are remarkable for their richness of animal life. The variety in climatic and other conditions, the nearness to the great continent of Asia and to the chief center of marine life—the East Indian Islands—its relation to the warm Black Current or Kuro Shiwo—the Gulf Stream of the Orient—and to the cold current from Bering Sea, all tend to give variety to the fauna of its seas. Especially numerous and varied are the fishes of Japan.

About nine hundred species of fishes are known, from the four great main islands of Japan, and about two hundred more from the volcanic islands (Kuriles and Liu Kiu) to the north and south. Of the eleven hundred, about fifty are fresh water. All these are derived from the mainland of Asia. Two faunal districts, the north and the south, may be recognized among the fresh-water fishes. The mountain region and the region lying to the north of Fuji abound in trout, with salmon, sturgeon, lamprey and other northern fishes. In the southern district these are absent and the chief fresh-water fishes are ayu, or dwarf salmon, chubs, minnows, cat-fishes and loaches.

The marine fishes are far more varied, their distribution being mainly controlled by temperature and currents. Among these, five districts may be recognized, their range sufficiently indicated by the names, Kurile, Hokkaido, Nippon, Kiusiu, Kuro Shiwo and Liu Kiu. Of these, the Kurile Fauna is subarctic, similar to that of the Aleutian Islands, that of the Liu Kiu islands is tropical, that of the promontories, which strike out into the Kuro Shiwo, is Polynesian. The central region (Nippon) contains the forms essentially Japanese. Kiusiu has much in common with China, and Hokkaido with Siberia and Manchuria. Each of these districts overlaps, by a broad fringe, on the others.

It has been noted that the fish fauna of Japan bears a striking resemblance to that of the Mediterranean, and Dr. Günther has suggested that this can be accounted for by supposing that in recent times a continuous coast line and sea-passage extended from one region to the other, the Isthmus of Suez not existing.

The resemblance consists in the presence in the two regions of certain striking-looking fishes not found in other parts of the world. An analysis of these resemblances takes away much of their impressiveness. Most of the forms in question are widely distributed, ranging from Japan through India to the Cape of Good Hope. Only three genera are restricted to Japan and the Mediterranean. Resemblances equally strong exist between Japan and the West Indies, or between Japan and Australia. The differences are equally marked. The types regarded as of Japanese origin are all wanting in the Mediterranean. Those of Mediterranean origin are wanting in Japan. There are two main reasons why one fish fauna may resemble another; the one, actual connection, so that fishes migrate from one region to another; the other, similarity of physical conditions, favoring in each region the development of similar kinds of fishes. The evidence points toward the theory that similarity of physical conditions is the chief source of resemblance between Japan and the Mediterranean. The resemblance between Japan and the West Indies is due to this cause, while that of Japan to the East Indies is due largely to direct connection. If Japan and the Mediterranean were ever connected, the Red Sea must have been a region of junction. Yet, while the Red Sea in its fishes closely resembles southern Japan, it has almost nothing in common with the Mediterranean. Except a few shallow water or brackish water types, the shore fishes of the two regions are wholly distinct, none of the characteristic genera of either sea being found in the other.

Yet, geologists affirm that in Pliocene or Post-Pliocene times the Isthmus of Suez was submerged. It is made up of Pliocene deposits with alluvium from the Nile and drifting sand-hills. Admitting this to be true, the nature of the fishes shows that this channel must have been very shallow and probably in part occupied by fresh water. No bottom-fish or rock-fish has crossed it—only sting-rays, torpedoes, eels and mullets appear to have passed from one side to the other. It must have been impossible for Japan and the Mediterranean ever to have exchanged their deep-water fishes in this way. The only other alternative is the Cape of Good Hope, and this barrier is, to this day, passed by many characteristic fishes of both oceans.

Four hundred and eighty-three genera of fishes are known from Japan. For the purpose of our present study we must take from this list all the fresh-water types, derived from China; all the northern types, derived from Bering Sea and the general Arctic stock; all the pelagic fishes, at home in the open sea, and all the bassalian fishes, or those inhabiting great depths below the range of climatic changes. After these are withdrawn, we have left the shore fishes of tropical, or semi-tropical, origin. Of these, Japan has 334 genera; the Mediterranean, 144; the Red Sea, 191; India, 280; Australia, 344; New

Zealand, 108; Hawaii, 144; West Indies, 299, and the Panama region, 256.

Common to Japan and the Mediterranean are 79, all but two being of wide distribution; to Japan and the Red Sea, 111; to Japan and Hawaii, 82; to Japan and Australia, 135; to Japan and the West Indies, 113; to Japan and Panama, 91. To the Mediterranean and the Red Sea, 40 genera are common, all of wide distribution; to the West Indies and the Mediterranean, 70, 59 being of wide distribution; to the West Indies and Panama, 179, only 101 being of wide distribution.

It is evident from an analytical table that the warm-water fauna of Japan, like that of Hawaii, is derived from that of the East Indies and Hindostan; that the fauna of the Red Sea is derived from the same source; that the Mediterranean fauna bears no special resemblance to that of Japan rather than to that of the other parts of Eastern Asia with like conditions of temperature and no greater than is borne by the West Indies; that the fauna of the two sides of the Isthmus of Suez have relatively little in common, while those of the two sides of the Isthmus of Panama show a remarkable degree of identity.

When the fishes of Panama were first described, it was claimed that their species were almost entirely identical with those of the West Indies; this statement was followed by speculations on the relation of the depression of this Isthmus to the Gulf Stream, and to the glacial epoch. Further investigations by Jordan, and by Evermann and Jenkins showed the fallacy of this claim of identity. Of about 1,400 species now known from the two sides of the Isthmus, only 70 are identical, or five per cent. of the whole, and about 10 of these are almost cosmopolitan in the tropics. Dr. Paul Fischer finds about three per cent. of the mollusks identical on the two coasts.

Dr. R. T. Hill goes on to show that there is neither geological nor biological evidence of the submergence of the Isthmus of Panama since Tertiary times, and that such a barrier existed as far back as Jurassic times. There is, however, evidence of a brief connection in Tertiary time at the end of the Eocene period.

Assuming this to be true, the actual facts of distribution seem to be in accord with it. The period of depression was before the life-time of most of the present species. It was, however, not earlier than the period of most of the present genera. It was relatively shallow, but wide enough to permit the infiltration from the Caribbean Sea to the Pacific of species representing most of the genera of sandy bays, rocky tide pools and brackish estuaries. Since the channel was closed, the species left on either side have undergone modification in varying degrees, mostly retaining generic identity, while losing some of their specific characters.

Doubtless, local oscillations in coast lines have taken place and are even in operation at present, but the time has passed when a dance of continents can be invoked to explain anomalies in animal distribution. Most of these will be found to have simple causes, when we know enough of the facts in the case to justify a hypothesis.

The laws governing animal distribution are reducible to three very simple propositions:

Every species of animal is found in every part of the earth having conditions fit for its existence, unless

(*a*) Its individuals have been unable to reach the region in question through barriers of some sort, or,

(*b*) Having reached the region, the species is unable to maintain itself through lack of capacity for adaptation, through severity of competition with other forms, or through destructive conditions of environment, or else,

(*c*) Having entered and maintained itself, it has become so altered in the process of adaptation as to become a species distinct from the parent type.

In general, the different types of fishes are most specialized along equatorial shores. The processes of change through natural selection take place most rapidly there and produce more far-reaching modifications. The coral reefs of the tropics are the centers of fish-life, corresponding in fish economy to the cities in human affairs. The fresh water, the Arctic waters, the deep sea and the open sea represent ichthyic backwoods—regions where change goes on more slowly and in which archaic types survive.

The study in detail of the distribution of the fishes of the tropics, is most instructive. The study of the origin of the fish groups of Japan affords a fascinating introduction to its multifarious problems.

THE OMEN ANIMALS OF SARAWAK.

By A. C. HADDON, F.R.S.,

CAMBRIDGE UNIVERSITY.

THE cult of the omen animals is of such importance in the daily life of most of the tribes of Borneo that it is desirable that more attention should be paid to it by those who have the opportunity of studying it at first hand.

The Venerable Archdeacon J. Perhamhas given a full account of the Iban or Sea Dayak religion in the 'Journal of the Straits Branch of the Royal Asiatic Society' (Nos. 1, 2, 3, 4, 5 and 8), which has been reprinted by Ling Roth in his book, 'The Natives of Sarawak and British North Borneo.' Mr. Ling Roth has also compiled some other scattered references on omens (Vol. I., pp. 221–231). Although the following notes are very imperfect, they contain some new facts derived from Dr. C. Hose, and also, thanks to information derived from Dr. Hose, I am able for the first time to give a fairly complete list of the omen animals of Sarawak, with their scientific names. I have taken the liberty of abstracting the following account of the way in which birds are 'used,' as the Ibans say, from Archdeacon Perham's most valuable papers, as it is the best description known to me of what is of daily occurrence in Borneo:

> The yearly rice farming is a matter of much ceremony as well as of labor with the Dayaks, and must be inaugurated with proper omens. Some man who is successful with his padi will be the augur and undertake to obtain omens for a certain area of land, which others besides himself will farm. Some time before the Pleiades are sufficiently high above the horizon to warrant the clearing the grounds of jungle or grass, the man sets about his work. He will have to hear the *nendak* (Cittocincla suavis) on the left, the *katupong* (Sasia abnormis) on the left, the *burong malam* (a locust) and the *beragai* (Harpactes duvauceli) on the left, and in the order I have written them. As soon as he has heard the *nendak*, he will break off a twig of anything growing near and take it home and put it in a safe place. But it may happen that some other omen bird, or creature, is the first to make itself heard or seen, and in that case the day's proceeding is vitiated; he must give the matter up, return and try his chance another day; and thus sometimes three or four days are gone before he has obtained his first omen. When he has heard the *nendak*, he will then go to listen for the *katupong* and the rest, but with the same liability to delays; and it may possibly require a month to obtain all those augural predictions, which are to give them confidence in the result of their labors. The augur has now the same number of twigs and sticks as birds he has heard, and he takes these to the land selected for farming and puts them

in the ground, says a short form of address to the birds and Pulang Gana (the tutelary deity of the soil, and the spirit presiding over the whole work of rice farming), cuts a little pass or jungle with his parang and returns. The magic virtue of the birds has been conveyed to the land.

For house-building the same birds are to be obtained and in the same way. But for a war expedition, birds on the right hand are required, except the *nendak*, which, if it make a certain peculiar call, can be admitted on the left.

These birds can be bad omens as well as good. If heard on the wrong side, if in the wrong order, if the note or call be of the wrong kind, the matter in hand must be postponed, or abandoned altogether; unless a conjunction of subsequent good omens occur, which, in the judgment of old experts, can overbear the preceding bad ones. Hence, in practice, this birding becomes a most involved matter, because the birds will not allow themselves to be heard in straightforward orthodox succession. After all, it is only a balance of probabilities; for it is seldom that Dayak patience is equal to waiting till the omens occur, according to the standard theory.

These are the inaugurating omens sought in order to strike a line of good luck, to render the commencement of an undertaking auspicious. The continuance of good fortune must be carried on by omen influence to the end.

When any of these omens, either of bird, beast or insect, are heard, or seen by the Dayak on his way to the padi lands, he supposes they foretell either good or ill to himself or to the farm; and in some cases he will turn back and wait for the following day before proceeding again. The *nendak* is generally good, so is the *katupong*, on the right or left, but the *papau* (Harpactes diardi) is of evil omen, and the man must beat a retreat. A *beragai* heard once or twice matters not; but if often, a day's rest is necessary. The *mbuas* (Carcineutes melanops) on the right is wrong, and sometimes it portends so much blight and destruction that the victim must rest five days. The 'shout' of the *kutok* (Lepocestes porphyomelas) is evil, and that of the *katupong* so bad that it requires three days' absence from the farm to allow the evil to pass away; and even then a *beragai* must be heard before commencing work. The *beragai* is a doctor among birds. If the cry of a deer, a *pelandok* (Tragulus), be heard, or if a rat crosses the path before you on your way to the farm, a day's rest is necessary; or you will cut yourself, get ill or suffer by failure of the crops. When a good omen is heard, one which is supposed to foretell a plentiful harvest, you must go on the farm and do some trifling work by way of 'leasing the work of your hands' there, and then return; in this way you clench the foreshadowed luck, and at the same time reverence the spirit which promises it. And should a deer, or *pelandok* come out of the jungle and on to the farm when you are working there, it means that customers will come to buy the corn and that therefore there will be corn for them to buy. This is the best omen they can have, and they honor it by resting from work for three days.

But the worst of all omens is a dead beast of any kind, especially those included in the omen list, found anywhere on the farm. It infuses a deadly poison into the whole crop and will kill some one or other of the owner's family within a year. When this terrible thing happens they test the omen by killing a pig and divining from the appearance of the liver immediately after death. If the prediction of the omen be strengthened, all the rice grown on that ground must be sold; and, if necessary, other rice bought for their own consumption. Other people may eat it, for the omen only affects those at

whom it is directly pointed. A swarm of bees lighting on the farm is an equally dreadful matter.

The 'barking' deer *(Cervulus muntjac)* is very important as an omen to all peoples, but least so to the Ibans. The bark of this deer prevents people from continuing their journey, and even divorces people who are newly married.

The little chevrotains, 'planok' or 'plandok' *(Tragulus napu* and *T. javanicus),* have the same function as the muntjac, so far as a journey is concerned, but otherwise they are not very important.

The Rev. W. Chalmers says: "If the cries of any of the three kinds of deer found in Sarawak be heard when starting on a journey, or when going to consult the birds by day or by night, it is a sign that if the matter in hand be followed up sickness will be the result. Also, if a newly married couple hear them at night, they must be divorced, as, if this be not done, the death of the bride or bridegroom will ensue. I myself have known instances of this omen causing a divorce, and I must say the separation has always been borne most philosophically by the parties most concerned; in fact, the morning of one of these divorces I remember seeing an ex-bridegroom working hard at shaping some ornamental brass-work, which Dayak women are in the habit of wearing round their waists, and he said that he intended to bestow it on a certain damsel whom he had in his eye for a *new* wife."

Sir Spencer St. John writes: "To hear the cry of a deer is at all times unlucky, and to prevent the sound reaching their ears during a marriage procession, gong and drums are loudly beaten. On the way to their farms, should the unlucky omen be heard, they will return home and do no more work for a day."

A Malay told me: If a Sarawak Malay was striking a light in the evening in his house and a plandok made a noise at the same time, the whole family would have to leave the house for three days. Should they not do so, the house would catch fire and be burned down or sickness or other calamity would overtake them.

On the second day of one of Dr. Hose's journeys through the jungle, the chief who was with him saw a plandok rush across the path. Hose being behind, did not observe it, but he saw all his party sitting on a log, and the chief informed Hose that he could not proceed that day, as his 'legs were tied up.' This was most inconvenient, as Hose was in a hurry, but the men would not go on. Hose freely took upon himself all the responsibility and said he would go first and would explain to the plandok that he was the person in fault. The chief would not agree even to this, and did not budge, but said he would follow the next day. Hose went on with some of the men as far as he could get and camped. Next day the chief caught Hose up at noon and appeared very much

surprised that no harm had befallen him. Hose chaffed him about his legs and was 'pleased to see that they had become untied!'

The small viverrine carnivore *(Arctogale leucotis)* is one of the most important omens for Kenyahs and Kayans, who, however, have a particular dread of coming into contact with it. Lest it should produce sickness, they will never even touch a piece of its dried skin. It is not an omen for the Ibans, nor for the Punans, who even kill and eat it. After having obtained other omens, the Kayans are glad to see the munin, as it is useful in conjunction with other omens, but they do not like to hear it squealing.

The screeching of the large hawk *(Haliastur intermedius)*, which is closely allied to or a sub-species of the Brahminy kite *(H. indus)*, is a cautionary sign with the Kayans, and though it is not in itself a bad sign, they will generally return home from any enterprise on hearing it, if they were still taking omens, or, at all events, they will remain where they are for a day. What the Kayans and Kenyahs most desire when 'owning' a hawk is to see it skim silently, without moving its wings, either to the right or to the left. Any other action than this, such as a swoop down or continued flapping of the wings, is considered unfavorable. Something bad is going to take place; they do not know what it may be or to whom it will happen, and one who sees the hawk do this turns away his face or retires to some place out of the sight of the hawk, lest, on being observed, he should be the one on whom the misfortune will fall. On such an occasion no one speaks a word, and all return into the house and wait from ten minutes to half an hour. If they are very anxious to go on again that day, they slip quietly out of the house, so that the hawk may not see them, get into their boats and start on their journey.

If the hawk appears on the wrong side when men are paddling, a few days away from home and nearing another village, they immediately turn the boat right round, pull to the bank and light a fire. By turning round they put the hawk on the right side, and, being satisfied in their own minds, they proceed on their journey as before.

The hawk, or, as the Ibans call it, Sengalong Burong, is a very important being. The little woodpecker *(Sasia abnormis)*, 'Katupong' is his son-in-law, being married to Dara Inchin Temaga Indu Monkok Chilebok China, a poetical *hantu*, who mentions in her songs the names of all the mouths of the rivers in their order from Sarawak River to some distance up the coast. (This is probably the remnant of a migration saga.) The smallest of the trogons, *Harpactes duvauceli*, 'Beragi,' also married another daughter of Sengalong Burong.

Although this is the most important of any Iban omen bird, it is his sons-in-law that are most used. Food is offered to Sengalong Burong.

I believe that other large hawk-like birds are used as omens. The Brahminy Kite is popularly supposed in India to be the sacred Garuda, the mythical bird, half eagle and half man, which, in Hindu mythology, is the *Vahana,* or vehicle of Vishnu. Whenever Bengali children see one of these birds they cry out:

Let drinking vessels and cups be given to the Shankar Chil (Brahminy Kite),
But let the Common Kite get a kick on its face.

There is a kingfisher that lives in the jungle *(Carcineutes melanops)* which is not a particularly lucky bird. If, when they are making a trap, the Ibans hear the long, mournful whistle of the 'Membuas,' they know that, although the trap will catch things, it will only be after an interval of ten to fourteen days that they will have any luck. On other occasions it is not unusual for them to catch little partridges, such as *Rollulus rouloul,* directly they have set up the trap, but often, under ordinary circumstances, it will be a day before they catch anything.

The Kenyahs apparently dislike this bird, which they call 'asi,' as it is not very favorable; in fact, they would rather not see it.

The white-crested hornbill *(Berenicornis comatus),* which has a moderate-sized black-keeled casque on its beak and bare blue orbits and throat, is an omen that is sought for by Kenyahs and Kayans, particularly by the latter, when felling jungle for planting and when going on the war-path. The Kenyahs use it slightly, and the Ibans not at all; it is, in any case, an omen bird of secondary importance.

The trogon, called by the Ibans 'Papau' *(Harpactes diardi),* is particularly useful to these people when hunting in the jungle for deer, pigs, etc., as it is a sure sign that they will obtain something that day; the bird's note of 'Pau, pau, pau,' infuses fresh energy into them. Supposing some Ibans were making a spring-trap *(panjok),* the moment one of them heard the cry of the 'Paupau' or 'Beragai' *(H. duvauceli),* he would at once snap off or cut off a small twig with a parang; the small piece of wood then cut or broken off is used for the release of the trap; the man would at the same time remark to the bird, 'Here we are.'

Other tribes such as the Kenyahs and Punans use *Harpactes diardi* as an omen, but it is not an important one. *H. duvauceli,* on the contrary, is of very considerable importance to the Kenyahs when going on the war-path, it being one of the omens of which it is imperative to obtain a sight or hearing. *H. kasumba* is employed indifferently with *H. diardi.*

Lepocestes porphyromelas is one of the most important of the omen birds, as it makes two perfectly distinct notes, one of which is favorable and the other unfavorable. On a rainy day it calls 'tok, tok, tok,' but

when the sun comes out it bursts into long 'kieng, kieng'; 'tok' is bad, but 'kieng' is good.

When a Kenyah hears the 'tok' cry, he immediately stops, lights a fire and takes the usual precautions in talking to it. He knows perfectly well that the same bird makes the two notes, and he waits for the 'kieng.' His explanation is that when the bird calls 'tok' it is angry, and that it is in a good temper when it sings 'kieng,' and therefore it is well not to go contrariwise to the omen. The Ibans behave in a similar manner. The Kenyahs regard it as a bird of warning, but not one that assists in getting anything. If a man was doing anything with a parang, knife or other sharp-edged tool and heard even a 'kieng,' he would probably desist from further use of it for that day.

The little woodpecker *(Sasia abnormis)* is in high favor among the Ibans; in fact, they consider it most important, as he represents his father-in-law, 'Sengalong Burong.' The 'Katupong' appears to produce whatever result they require. It is of less importance with other peoples of Sarawak.

Mr. Crossland informs us if a katupong enters a house at one end and flies out the other, men and women snatch up a few necessaries, such as mats and rice, and stampede, leaving everything unsecured and the doors unfastened. If any one approaches the house at night, he will see large and shadowy demons chasing each other through it, and hear their unintelligible talk. After awhile the people return and erect the ladder they have overthrown, and the women sprinkle the house with water 'to cool it.'

A kind of thrush *(Cittocincla suavis)* is particularly useful to the Ibans when looking for gutta or other jungle produce. 'Nendak' is a good bird too for them to own, as it is a Burong chelap, and, on hearing it, they would not be afraid of any sickness.

Before starting on a gutta expedition, they would require to see something before 'beragai' *(Harpactes duvauceli)*, as this is a 'burong tampak,' that is, an omen animal that is potent for hunting. What they like is: First, to get 'nendak,' then wait three days while they are owning it, finally to get 'beragai' on the right. This combination signifies certain success; not only would they find gutta, but would obtain plenty of it, and no harm or sickness would befall them. If, however, they went for gutta on 'beragai' alone, and that, perhaps, appeared on the left, they would obtain a fair amount of gutta, but they would stand a good chance of some misfortune happening to them, and one of their party might fall sick, or even die.

The Tailor bird *(Orthotomus cineraceus)*, although employed by Ibans only, is of very little use, as it is only a secondary burong. It may be employed as an additional argument when deciding for 'Selam,' or trial by the water ordeal. This consists in the two dispu-

tants putting their heads under water, and the one who has the most staying power having right on his side.

The Bornean shrike *(Platylophus coronatus)*, which has an erectile crest of long and broad feathers on its head, is used by the Ibans as a weather prophet on account of its unerring faculty of foretelling a storm, for whenever its whistle is heard, rain is always to be expected. It is very important for Kenyahs and Kayans in connection with tilling farms. When Kayans are clearing any undergrowth for a farm, after having offered to 'Niho' *(Haliastur intermedius)* and other omen animals, it is desirable that they should hear 'pajan,' the shrike, for then they know they will get plenty of padi of good quality, but there will be a good deal of hard work, and possibly a considerable amount of sickness and cuts and wounds. If they procure this omen, they take the precaution of building very substantial granaries.

Three species of Sun birds *(Arachnothera longirostris, A. modesta* and *A. chrysogenys)* are very important to Kayans, Kenyahs and Punans. Any of these species is used impartially, and they bear the name of 'Sit' or 'Isit.'

The 'Sit' is always the first bird to look for when undertaking anything—fortunately, an individual of one of the three species is almost always to be seen crossing the river. It is one of the least important omen birds with the Ibans. When Kayans, Punas and Melanaus go in search of camphor, it is first necessary to see a 'Sit' fly from right to left, and then from left to right. A Melanau, who is intending to start on such an expedition, sits in the bow of his boat and chants:

"O Sit, Sit, ta-au, Kripan murip, Sit,
Ano senigo akau, ano napan akau.
Oh! Sit, Sit, on the right, give me long life, Sit,
Help me to obtain what I require, make me plenty of that for which I am looking."

An allied bird, *Anthreptes malaccensis*, is commonly mistaken by Kayans, but by them only, for *Arachnothera longirostris*. They use it as an omen bird, but it is not so used by the Kenyahs, by whom it is called 'Manok Obah.'

All the omen snakes are bad omens, and in the case of a Kayan seeing 'batang lima' *(Simotes octolineatus)*, he will endeavor to kill it and, if successful, no evil will follow; should he fail to kill it, then 'look out.'

I believe that the Ibans pay some regard to 'Sawa,' a large python *(Python reticulatus)* and to 'Tuchok,' a kind of Gecko *(Ptychozoon homalocephalum)*, and to 'Brinkian,' another kind of Gecko; but I do not know whether these are, strictly speaking, omen animals.

The omen padi-bug, 'turok parai' *(Chrysocoris eques)* is only of importance, and that to Kenyahs alone, because it injures the crops.

The bee 'Manyi' *(Melipona vidua)* is an Iban omen only. If a swarm of bees settled underneath a house that had recently been built, it would be considered a bad sign, and probably it would be necessary to destroy that particular section of the house or to leave the house altogether.

Many Land Dayaks, on the contrary, keep bees in their houses, and among most of the peoples of Borneo, including the Ibans, it is most lucky in planting time to dream of an abundance of bees.

There are other creatures whose appearance, cry or movements may signify good or bad luck which are not omen animals (*i. e.*, 'burong' or 'aman'), in the strict sense of the term. For example, the hawk owl *(Ninox scutulata)* makes a melancholy cry at night, on account of which it is very much disliked by the natives, who regard it as a foreteller of death. Its native name is 'Pongok.' If the Malay bear *(Heliarctos Malayanus)* climbs into an Iban's house, it is a bad sign, and the house would have to be pulled down.

According to Perham: "In answer to the questions of the origin of this system of 'birding,' some Dayaks have given the following: In early times the ancestors of the Malays and the ancestors of the Dayak had, on a certain occasion, to swim across a river. Both had books. The Malay tied his firmly in his turban, kept his head well out of water, and reached the opposite bank with his book intact and dry. The Dayak, less wise, fastened his to the end of his waist-cloth, and the current washed it away. But the fates intervened to supply the loss and gave the Dayak this system of omens as a substitute for the book."

Another story relates the following:

> Some Dayaks in the Batang Lupar made a great feast and invited many guests. When everything was ready and arrivals expected, a tramp and hum, as of a great company of people, was heard close to the village. The hosts, thinking it to be the invited friends, went forth to meet them with meat and drink, but found, with some surprise, they were all utter strangers. However, without any questioning, they received them with due honor and gave them all the hospitalities of the occasion. When the time of departing came, they asked the strange visitors who they were and from whence, and received something like the following reply from the chief: I am *Sengalong Burong*, and these are my sons-in-law and other friends. When you hear the voices of the birds (giving their names), know that you hear us, for they are our deputies in this lower world.' Thereupon the Dayaks discovered they had been entertaining spirits unawares, and received as reward of their hospitality the knowledge of the omen system.

Archdeacon Perham is perfectly right in his statement that:

> "The sacredness of the omen birds is thus explained: They are forms of animal life possessed with the spirit of certain invisible beings above, and bearing their names; so that when a Dayak hears a 'Beragai,' for instance, it is really the voice of 'Beragai,' the son-in-law of Sengalong Burong; nay, more,

the assenting nod or dissenting frown of the great spirit himself. . . . 'These birds,' says Sengalong Burong, 'possess my mind and spirit, and represent me in the lower world. When you hear them, remember it is I who speak for encouragement or for warning.' . . . The object of the bird-culters is like that of all other rites: to secure good crops, freedom from accidents and falls and disease, victory in war, profit in exchange and trade, skill in discourse and cleverness in all native craft."

We know that such very distinct peoples in Sarawak alone, as the Ibans (Sea Dayaks), Land Dayaks, Muruts, Punans, Kayans and Kenyahs, pay attention to omen animals and, in most cases, to the same animals. This points to a common origin of the cult, for in some cases there is no specially obvious reason why that particular species of animal should have been selected. In the three last mentioned peoples the names of the omen animals are practically similar, but many of the Iban names are different.

There can be little doubt that this cult is indigenous to Borneo; it is probable that a cult of omen animals formed part of the fundamental religious equipment of the Ibans before they migrated to Borneo, but it is also probable that the Ibans have borrowed somewhat from neighboring indigenous tribes. Much more information must be obtained before a satisfactory history of this cult can be written.

SCIENTIFIC LITERATURE.

THE METRIC SYSTEM.

To one of scientific tastes, who at the same time welcomes the recent American renaissance of the historical novel, or to one whose faith in the common sense of his countrymen may waiver on considering their apathy towards the metric system, a recent work by M. Bigourdan* will have great fascination. Nor are these words carelessly chosen, for a more fascinating work on any phase of the history of science has not appeared in recent years. It is true that the topic seems trite enough. All the world knows the story, or thinks it does; the French revolution, the general upheaval, the different systems proposed, Méchain's mistake in the longitude of Barcelona, the consequent error in the meter, the final adoption of the system by a large majority of the civilized countries, all this is familiar. But one has only to read a dozen pages of M. Bigourdan's work to find himself in the midst of a wealth of interesting history of which he probably never even heard.

The fact is, it needed some one connected with the Paris Observatory to write such a work, and even he could not have done it until of late. For although the observatory has long had in its possession the original documents deposited there by virtue of a decree of the year 12, it is only recently that it received the valuable manuscripts relating to the early history of the system, which were given by Mme. Laugier, who had received them from her father, M. Mathieu, who in turn had them from a no less important actor in the drama than M. Delambre himself.

It is impossible to give in a few words any worthy *résumé* of the work, or adequately to speak of its style. It opens with a chapter on the precursors of the reform, going back even to the system under Charlemagne, to the effects of feudalism and to the efforts of such early leaders as Mouton, Huyghens and Wren. This is followed by a statement of the action of the Assembly on Talleyrand's proposition, the history of the provisional meter, the work of the temporary commission, the efforts at nomenclature and so on through the establishing of the system on a scientific foundation. Then come the long story of its adoption by France, ending with the law of July 4, 1837; the longer story of its struggles for recognition in other countries, and the later history of the International Bureau and its remarkable metrological labors at St. Cloud,

Still less is it possible to give, in the limited space at command, any idea of the thrilling historic action so unassumingly stated in the documents at M. Bigourdan's command. The difficulties of men like Delambre and Méchain, unable to make surveys without being suspected of signaling to the enemy, arrested as spies because they wished to visit their triangulation stations, imprisoned, insulted, limited in the bare necessities of life, the only wonder is that other errors than that of Méchain did not find frequent place in the work. 'I am an academician,' said Delambre to a sansculotte who

* 'Le systéme métrique des poids et mesures. Son éstablishment et sa propagation graduelle, avec l' histoire des opérations qui ont servi a déterminer le métre et le kilogramme.' Paris, Gauthier-Villars, 1901; pp. vi+458; price 10 fr.

examined his passports. 'There isn't any *Cadémie*, no *Cadémie* at all,' blurts out the surly guard; 'all the world's equal. You come along with us!'

To the American scientist, educator or promoter of foreign trade, however, the chief interest in the work lies in the story it tells of the adoption of the system by most of the non-English-speaking countries of the world. The common objections of those who have given the subject little thought, objections to nomenclature, to the magnitude of the units, to the difficulty of educating the people, to the error in the meter, objections which have been so thoroughly considered in the century past and in so many countries, and which have proved of so little consequence—these are considered fully and judiciously. It will be unfortunate if some of the societies interested in the progress of the system do not arrange for translating the entire work, both for the enlightenment of those who have given the subject little attention and for the help of those who believe that America can no longer afford to stand out against a system which the great majority of civilized nations are using.

BOOKS ON NATURE STUDY.

'The Sea-beach at Ebb-tide,' by Augusta Foote Arnold (The Century Co.), meets a well-defined need for popular accounts of the natural history of the seaside. It describes the animal and plant life found on the beach and rocks between tide marks and washed up after storms. There are chapters on the distribution of animals and plants, on methods of collecting and preservation, on classification and on various peculiarities of certain groups. Then follows an account of the marine algæ and marine invertebrates, systematically arranged with the formality of a manual. This portion of the book is abundantly illustrated with photographic reproductions. Some of these are very good, but many are not as clear as could be wished and do not compare favorably with the beautiful book work exhibited in some of the recent popular accounts of flowering plants. That the book is far from being strictly accurate becomes apparent to any one who critically examines the treatment of groups with which he is familiar. Nevertheless the conspicuous forms are in the main sufficiently described and, what is more important, so figured that the tyro will have little difficulty in identifying specimens at hand. There is sure to be much confusion, however, of the more minute types such as the hydroids with the delicate filamentous seaweeds that should be studied with the compound microscope.

The author's attitude towards classification seems strained. The account of every large group is prefaced by a table of the families, genera and species to be considered. These synopses remind one of the outlines found in dictionaries and are very far from the spirit of classification that now dominates natural history. Such arrangements have but small and passing value in the constantly shifting scenes of systematic zoology and botany. Emphasis laid upon classification throws into the background the wealth of interest in the life and habits of organisms which we term their natural history. But a more important criticism is the loose and inaccurate conception of the significance and use of nomenclature. When the author says that specific names are 'occasionally the names of botanists who first described the plants' (p. 29), she shows much ignorance of the methods of systematists. It seems that the spirit of the present-day natural history is rather against collecting, that the best thought is directed to the out-of-doors study of particular groups in some detail rather than to the recognition of a very large number of forms, to the study of their home life with camera and sketch book rather than to

their collection and preservation. And the most interesting popular books on natural history in recent years have exhibited a very intimate knowledge of the forms considered. There is a charm in familiar friendship that is far more satisfactory than casual acquaintance, and it is a matter of small importance what the forms are—whether birds or bees or some group of plants.

One can hardly ask for a better piece of book work than 'Flowers and Ferns in their Haunts' by Mabel Osgood Wright (Macmillan). The charm lies in the beautiful photographic reproductions. These exhibit the details of flowers or ferns in the foreground against rock and in other picturesque situations with a sharpness that is very remarkable and in most delicate contrast to the soft backgrounds. With this detail is a choice of subjects in their surroundings that shows great feeling for the appropriate and artistic. The text is a running account of walks and rides in woods and over hill and dale in varying seasons of the year. The descriptions, chiefly of flower societies, are quite free from technicalities. The point of view is always imaginative and human rather than scientific. The book can scarcely be said to be botanical, except that flowers form the subject of a pleasing account of nature in her varying moods always treated figuratively and with much personification. Two human characters beside the author are carried through the book, one a quaint and interesting old man, the other a conventionally educated young woman, whose presence except as a foil seems somewhat out of place in these pages.

THE PROGRESS OF SCIENCE.

FOREIGN ASSOCIATIONS FOR THE ADVANCEMENT OF SCIENCE.

The national scientific associations of Great Britain, Germany and France held their annual meetings during the month of September. The British Association met at Glasgow, under the presidency of Professor A. W. Rücker, the eminent physicist. Professor Rücker, who has recently been elected president of the reorganized University of London, gave an excellent address on the present trend of opinion in regard to the atomic theory; and the addresses of the presidents of the sections were of the usual high order. The section of education, organized for the first time, attracted special attention; we are, therefore, fortunate in being able to publish in this issue of the Monthly the presidential address of Sir John Gorst. The attendance at Glasgow—1,912—was above the average, but not so large as at the previous Glasgow meetings of 1855 and 1876, the sesquicentennial of the University, the Engineering Congress and other events having anticipated local interest in scientific matters. The sum of £1,000 was appropriated for scientific grants. The meeting of the Association next year will be at Belfast under the presidency of Professor James Dewar, the well-known chemist.

The seventy-third meeting of German Men of Science and Physicians was held at Hamburg, with Dr. R. Hertwig, professor of zoology at Munich, as president. Professor J. H. Van't Hoff, the eminent chemist of Berlin, was president of the scientific sections and Professor B. Naunyn, professor of medicine at Strassburg, of the medical sections. There were in all twenty-seven sections for the medical sciences and eleven for the natural and exact sciences. The attendance was large—some 5,000 members—and the programs important. Special lectures were given by Dr. E. Lecher on 'Hertzian Waves,' by Professor T. Boveri on 'Fertilization' and by Professor W. Nernst on 'Electro-chemistry.'

The French Association met on the Island of Corsica under the presidency of M. Hamy, whose address reviewed the beginnings of anthropology in France. Owing doubtless to the centralization of scientific work at Paris, the migratory meetings of the French Association are less well attended than those of Germany and Great Britain, and the papers presented are less numerous and important. The Association, however, performs a useful work, and having a large endowment (some $270,000) is able to make liberal grants for scientific research.

PROFESSOR PAWLOW'S RESEARCHES ON NUTRITION.

The award of the first Nobel prize to Professor J. P. Pawlow, the widely known physiologist of St. Petersburg, is a well-deserved testimonial to his valuable and extensive contributions to experimental science. During the last twelve years Professor Pawlow has been engaged more particularly in the study of certain aspects of nutrition, and in this work he has enlisted the services of a considerable number of co-workers in his laboratory at the Imperial Institute for Experimental Medicine in St. Petersburg. The researches which these years brought forth have led physiologists to revise in many particulars the current teaching in regard to digestion and secretion. Most of the results obtained by Pawlow and his pupils were originally published in the 'Archives des Sciences Biologiques de St. Petersbourg,' and in inaccessible Russian journals and

dissertations. The more important facts and conclusions were, however, collected and presented in organized form in a series of lectures delivered at the Institute for Experimental Medicine. These lectures, originally published in Russian, have been translated into German and issued in book form ('Die Arbeit der Verdauungsdrüsen,' Wiesbaden, 1898; J. F. Bergmann). They have been widely read and have received abundant praise everywhere.

The chief merit of Pawlow's work lies in the application of new experimental methods to the solution of important problems in the physiology of secretion and digestion. Thus the introduction of the combined œsophageal and gastric fistulas has led to original observations on the mechanism of secretion; while the possibility of obtaining pure gastric juice has given rise to renewed chemical investigation of the composition and properties of this secretion. By an ingenious method of isolating completely a portion of the stomach while keeping unimpaired the nerve distribution to the isolated part, still further advances have been made. Other methods have been applied by Pawlow to the study of the function of the pancreas and the production of the bile. The specific influence of the nervous system on secretion, and the paths along which this is exerted, have been ascertained more definitely than ever before. Pawlow's contributions to experimental technique in these departments of investigation are unique, and their influence is already shown in the renewed interest which they have aroused lately in the study of digestion in general. To the more purely chemical aspects, also, this brilliant investigator has directed his attention. A prominent German physiologist has remarked that so many noteworthy results have not been achieved by any single investigator (together with his pupils) since Beaumont and Blondlot, and, in more recent years, Heidenhain.

In addition to these researches, mention may be made of the splendid investigations on the seat of urea formation in the animal body, which were carried out conjointly with Professor Nencki. Here again it was the application of new experimental methods—the Eck fistula operation, by means of which direct communication is established between the portal vein and the vena cava in mammals—which inaugurated a fresh series of important contributions on the rôle of the liver in intermediary metabolism.

Aside from the clear analysis of the problems involved and the originality of the methods applied, accurate observation and unremitting energy characterize Professor Pawlow's work. Every result obtained is verified until it stands as a permanent fact. Physiologists will rejoice at the fitting recognition which such successful achievements have received.

ZINC IN DRIED FRUITS.

During the past few years the export of dried apples and other fruit from this country to the continent of Europe has been greatly interfered with by the presence of zinc; the discovery of traces of this metal in the fruit has been deemed sufficient ground for prohibiting its importation. The presence of the zinc has been accounted for by the zinc trays used in the fruit driers, but the abandonment of the metal for this purpose has not sufficed to free the fruit from suspicion. A service has been rendered American fruit growers by an investigation recently carried out by Herr Soltsien, of Görlitz. He was incited to this by the detection of quite a strong trace (0.0067 %) of zinc in some American 'evaporated apples,' which had evidently not been dried on zinc trays. He finds that when zinc is present in the soil or in the atmosphere, it is readily taken up by plants, and, by consumption of such contaminated vegetables and fruit, even into the human body.

This was confirmed by finding traces of zinc in a number of corpses. He enumerates many ways by which zinc was found to enter the soil, among which are the following: The drainage waters from many foundations contain considerable quantities of zinc. In all regions where zinc smelting is carried on, or where there are zinc or brass foundries, the vegetation contains zinc; this arises from the fact that the particles of zinc oxid are extremely light and are carried to great distances in the atmosphere. In one instance the effluent from a slaughter house was precipitated by an effective chemical for the purpose which was sold under the name of 'sulfate.' This precipitant was found to be a very impure zinc sulfate, containing much iron and manganese. The excess of the substance passed into the stream contaminating it with zinc, while the precipitate, consisting largely of zinc albuminate, went with the other slaughter house refuse as fertilizer. It is quite possible that much of the 'tankage,' so largely used in this country in the manufacture of fertilizers, contains no inconsiderable quantity of zinc. Where zinc is thus present in the fertilizer, it would be apt to pass in traces into the fruit raised on soil thus fertilized. It is reasonable to suppose that such minute quantities of zinc would be perfectly harmless when taken into the human system, but their detection would serve to throw unjust discredit upon American fruit growers, long after they have ceased to use zinc in any part of the evaporators with which the fruit can come in contact; at least when preparing dried fruit for the export trade, these precautions have for some time been taken.

AN ELECTROMAGNETIC BASIS FOR MECHANICS.

About forty years ago Maxwell pointed out the main features of the electromagnetic theory of light. This theory very soon supplanted the old mechanical wave theory, or the elastic solid theory; and now the fundamental notions in light are purely electric or electromagnetic in character. It is very remarkable, however, that aside from the change in the fundamental notions themselves the old theoretical structure remains to a very great extent unchanged and that even the old nomenclature lends itself easily to the needs of the new theory with few exceptions. The change that has followed upon Maxwell's work is very like the moving of a house from old to new foundations.

There is at the present time a prospect of a similar transfer of the entire subject of mechanics to a purely electromagnetic foundation. Every one realizes that the notions of inertia and of gravitation, and the principles involved in Newton's laws of motion are far too abstract in their nature, and as elemental notions they are far too complicated to be entirely satisfactory as a basis for the most concrete of the physical sciences. It seems that the theory of electromagnetism is to supply precisely what is needful to reduce mechanics to a more elemental basis. The change, if it come, will no doubt be similar to the change which has taken place in the theory of light; the superstructure of theoretical mechanics and even the nomenclature will remain to a great extent unaltered.

The possibility of explaining the inertia of matter electrically was first shown by Heaviside. A charged body has more momentum when moving at a given velocity than if it were not charged, and if the body is small enough in comparison with its charge *all* its momentum may be accounted for in this way.

The possibility of explaining gravitation was first pointed out by H. A. Lorentz, who attributes it to an excess of attractive over repulsive forces of electric charges.

A remarkable consequence of Heaviside's theory of inertia is that accelera-

tion is not strictly proportional to accelerating force and that kinetic energy is not strictly proportional to the square of the velocity of a moving body.

Up to the present time a very prominent feature of physical science has been the reduction of every kind of phenomenon to mechanics. The notional elements out of which nearly every theory is built up are essentially mechanical in their nature, if one may use the term mechanical in a broad sense to signify all kinds of geometrical, kinematical and dynamical relations. The reason for this preponderating rôle of mechanics is that, hitherto at least, only those theories are effectively useful which are built up out of sensuous elements, and nearly all our complicated sensations refer to space relations as perceived with the eye and to dynamic and space relations as perceived by the sense of touch and by the so-called muscular sense. It is not likely that the transfer of mechanics to an electromagnetic foundation will greatly affect the preponderating role of concrete mechanics in physical science.

TENDENCIES IN ZOOLOGY.

ZOOLOGY also has its fashions. The publication of the 'Origin of Species,' by establishing a new standpoint and new problems, led zoologists to an ever minuter study of comparative morphology, already made fashionable by the work of Cuvier, Johannes Müller and Owen. On the discovery of the chordate affinities of the Tunicates by Kowalewsky, in 1866, an impulse was given to the investigation of comparative embryology, in the hope of further information, which, viewed in the light of the biogenetic law, might add other links to the phylogenetic chain. And later, when the science of cytology came into definite existence, the embryologist, who at first was content to carry his studies back only so far as the gastrula, was incited to delve more deeply, and for a time cell-lineage became the fashion, while, following quickly in the footsteps of this, experimental morphology became a vogue. Not that this last was an entirely new department of investigation, but rather a revival under new conditions and points of view of the methods of study employed by Trembley and Spallanzani whose experimental researches on Hydra and the earthworm respectively have reached the dignity of classics.

The latest fashion, nature-study, as it is called, is likewise a revival of older methods. It is a rejuvenescence of the natural history of the ancients, a return to the methods of Gilbert White, methods which, while they have never failed to attract, have unfortunately been sadly neglected of late by the professional zoologist. The developments of his subject have been towards ever-increasing esoterism, until the stage has now been reached when the laity has lost touch with the professional and fails to appreciate the results which he elaborates in the privacy of his laboratory, surrounded by his complicated engines for cutting sections and his multitudinous reagent bottles. In so far as this new revival of natural history methods may serve to bring about again a *rapprochement* of the amateur and the professional, it is to be welcomed, and important additions to our knowledge of the habits and instincts of animals and the significance of these may be expected when men, specially trained in the methods of biological investigation and thought, turn their attention to these phenomena.

But the enthusiasm which usually accompanies investigation along a new line must not blind to the danger which lurks beneath. The hope which lies in the departure is that it will tend to place the study of instincts and habits on a scientific basis and yield scientific results founded on careful and accurate observations, that. in a word, it will bring order into the chaos of observa-

tions now on record. Of indiscriminate observation there has already been too much; what is needed is discrimination. There is danger that the camera may become as powerful a fetish as the microtome has been. To spend hours in most uncomfortable positions endeavoring to secure a nature picture is not necessarily self-sacrifice in the pursuit of science; it may result in the securing of a pretty picture but it may result in nothing more. Pretty photographs are of no more value than pretty microscope slides; both are valuable only for what may be learned from them, and it is the exercise of a discrimination between what may be merely pretty and what may be instructive that gives an observation scientific value. It is not more amateur photographers that are wanted but more historians of nature.

SCIENTIFIC ITEMS.

We regret to learn of the death at the age of sixty-six years of Edward W. Claypole, professor of geology at Throop Institute, Pasadena, Cal., and of the death of A. F. W. Schimper, professor of botany at Bâsle, who died on September 9, at the age of forty-five years.

The eightieth birthday of Professor Rudolf Virchow, which occurred on October 13, has been celebrated in Berlin with elaborate ceremonies. There was a reception in the Pathological Institute in the afternoon and a banquet in the dining hall of the Prussian Diet in the evening, followed by an official reception in the parliament hall. Professor Waldeyer, secretary of the Berlin Academy of Sciences, presented 50,000 Marks, subscribed by medical men in Germany toward increasing the Virchow research fund. The event was also celebrated in New York and other cities. The municipality of Berlin has resolved to call its new hospital, containing beds for 1,700 patients, the Virchowkrankenhaus.

A statue of Pasteur was unveiled on September 9, at Arbois, where he spent his childhood and his holidays in later life. The monument, erected at a cost of over $10,000, was designed by M. Daillon and represents Pasteur seated. On the pedestal are two bas-reliefs, one representing inoculation against rabies and the other agriculture profiting from Pasteur's discoveries. On the occasion of the unveiling addresses were made by M. Decrais, French minister of the colonies, and M. Liard, representing the Department of Public Instruction.

President Seth Low presented his resignation to the trustees of Columbia University on October 7. It was accepted with expressions of deep regret, and Dr. Nicholas Murray Butler, professor of philosophy and education, was made acting president.

Surgeon-general George M. Sternberg has returned to Washington after a tour of inspection in the Philippines.—Mr. John A. Fleming, of the U. S. Coast and Geodetic Survey, has arrived in Honolulu for the purpose of erecting and conducting a station for the study of terrestrial magnetism.

Mr. J. E. Spurr, of the U. S. Geological Survey, who has been employed for geological surveys by the Sultan of Turkey, has begun work in Macedonia and Albania.

The Fifth International Congress of Physiology was opened on September 17 in the physiological laboratory of the University of Turin, under the presidency of Professor Angelo Mosso. Sir Michael Foster was elected honorary president. More than 200 physiologists were present, and 186 communications were announced.—The Congress of the International Association for Testing Materials was held at Budapest, from September 9 to 14, under the presidency of Professor L. von Tetmajer, and was largely attended by engineers from all parts of the world.

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A MECHANICAL SOLUTION OF A LITERARY PROBLEM.

By Dr. T. C. MENDENHALL.

THE title given to this paper, chosen after much hesitation and with no little reluctance, is not to be looked upon as an assumption of the definite and final solution of the principal problem to which attention has been directed. As a matter of fact I have hoped to conceal, for at least a page or two, the identity of this principal problem, in order that no well intentioned and good natured reader might be driven away by what is a very general, not altogether reasonable, but quite natural, prejudice. Whatever may be thought of the problem or of the importance of its solution, it is believed that the method here suggested and applied will be found to be of interest and, possibly, of considerable value in certain linguistic studies.

Nearly twenty years ago I devised a method for exhibiting graphically such peculiarities of style in composition as seemed to be almost purely mechanical and of which an author would usually be absolutely unconscious. The chief merit of the method consisted in the fact that its application required no exercise of judgment, accurate enumeration being all that was necessary, and by displaying one or more phases of the mere mechanism of composition characteristics might be revealed which the author could make no attempt to conceal, being himself unaware of their existence. It was further assumed that, owing to the well-known persistence of unconscious habit, personal peculiarities in the construction of sentences, in the use of long or short words, in the number of words in a sentence, etc., will *in the long run* manifest themselves with such regularity that their graphic representation may become a means of identification, at least by exclusion. In the present

consideration the application of the method has been restricted to a study of the relative frequencies of the use of words of different lengths.

The method of procedure is simple and will be best explained by an example. One thousand words in 'Vanity Fair,' taken in consecutive order of course, were counted and classified as to the number of letters in each with the following result:

Letters—	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Words—	25	169	232	187	109	78	79	48	28	20	10	10	2	3

The graphic exhibition of this result is made by the well-known method of rectangular coordinates, using the number of letters in a word as the abscissa and the corresponding number of words in a thousand as the ordinate. On a sheet of 'squared' paper the numbers showing letters in each word, 1, 2, 3, 4, etc., are placed along the horizontal line and on the vertical above each of these is put a point whose distance from the base shows the number of corresponding words in every thousand, according to the scale shown at the left. These points are then joined by straight lines and the whole broken line may be called the 'word spectrum' or 'characteristic curve' of the author as derived from the group of words considered. The group of 1,000 words from 'Vanity Fair' enumerated above is thus graphically represented by the continuous line in Fig. 1, and the method of constructing the characteristic curve will be readily understood by comparing this with the numbers given. As a thousand is a very small number in a problem of this kind, the curve representing any single group of that number of words is practically certain to differ more or less from that of any other such group. In Fig. 1 the dotted line represents a group of 1,000 words, immediately following that already referred to. Perhaps the most astonishing thing about these two lines is not that they differ, but that they agree as well as they do. It is really remarkable that any marked peculiarity in the use of words is almost sure to be revealed in this way, even in comparatively small groups. In the two diagrams of Fig. 1 it is interesting to note their general sameness, especially as shown in a tendency to equality of words of six and seven letters and also in words of eleven and twelve letters.

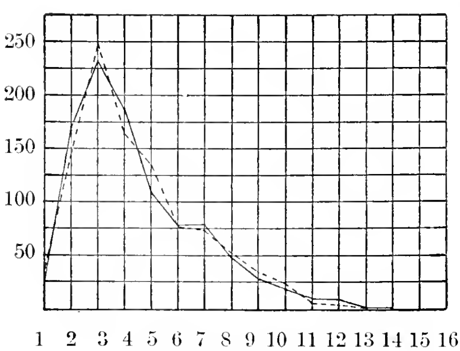


FIG. 1. TWO GROUPS—1000 EACH—VANITY FAIR.

When the number of words in each group is increased there is, of

course, closer agreement of their diagrams, and this became so evident in the earlier stages of the investigation that the conclusion was soon reached that if a diagram be made representing a very large number of words from a given author, it would not differ sensibly from any other diagram representing an equally large number of words from the same author. Such a diagram would then reflect the persistent peculiarities of this author in the use of words of different lengths and might be called the characteristic curve of his composition. Curves similarly formed from anything that he had ever written could not differ materially from this, although curves of other authors might possibly, but would not probably, agree closely with his.

Thus, if this principle were established, the method might be useful as a means of identification of authorship, and it might be relied upon with great confidence to show that a certain author did not write a certain composition.

In the earlier application of the method many interesting facts were brought out, some of which are worth mentioning here, although a full account of the preliminary work was published in 'Science' of March 11, 1887. It was soon discovered that among writers of English the three-letter word occurred much more frequently than any other. Indeed in the earlier investigation only one exception to this rule was found and that was in the writings of John Stuart Mill, who uses two-letter words more often than any other. This was surprising at first, especially in view of the large average word-length of Mill's composition, which is considerably in excess of that of any other author thus far examined, but it is easily explained by the very frequent appearance of prepositional phrases, necessitating the use of such two-letter words as *in, on, to, of,* etc., to an extent unapproached by other writers. Mill's writings furnished an opportunity for comparing the curves representing two different periods of an author's life. A comparison of two groups of 5,000 words each from his 'Political Economy' and his 'Essay on Liberty' showed the presence of the same peculiarities in word choosing, and in every thousand of the ten examined the two-letter word was in excess. No other writer of English has been found to use two-letter words oftener than any other, but it is not at all improbable that there may be such.

Through the interest of Mr. Edward Atkinson, it became possible to give a partial answer to the question, Can an author purposely avoid the peculiarities of style that belong to his normal composition? Mr. Atkinson, having addressed a body of college alumni on a certain topic, afterward gave what he meant to be the same address to a body of workingmen, but in the latter instance he made a special effort to use simple, short words and sentences of the simplest and plainest construction. Although relating to the same topic the two addresses 'read'

very differently, but their diagrams are strikingly alike in their main feature. As a matter of interest 'counts' were made of groups of about 5,000 words each from various languages other than English. The characteristic curves thus derived for Italian, Spanish, French, German, Latin and Greek are shown in Figs. 2 and 3, and, for convenience in comparison, that of Dickens's English is added. Many of these 'counts' were furnished by friends who became interested in the matter, and an incident of no little interest was the receipt of a column of numbers on a strip of paper with nothing to indicate its origin or meaning. Suspecting, however, that it might be a 'word count,' its diagram was constructed and it was instantly and beyond all reasonable doubt identified as coming from the Latin of Cæsar.

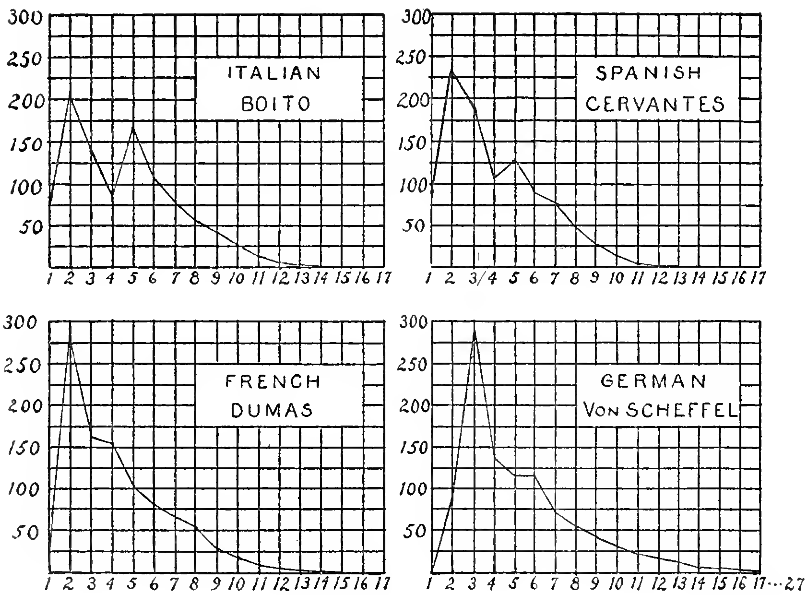


FIG. 2.

The original published description referred to above concludes as follows:

From the examinations thus far made I am convinced that 100,000 words will be necessary and sufficient to furnish the characteristic curve of a writer—that is to say, if a curve is constructed from 100,000 words of a writer, taken from any one of his productions, then a second curve from another 100,000 words would be practically identical with the first and that this curve would, in general, differ from that formed in the same way from another writer, to such an extent that one could always be distinguished from another. To demonstrate the existence of such a curve would require the enumeration of the letters of several hundred thousand words from each of a number of writers. Should its existence be established the method might then be applied to cases

of disputed authorship. If striking differences are found of known and suspected compositions of any writer, the evidence against identity of authorship would be quite conclusive. If the two compositions should produce curves which are practically identical, the proof of a common origin would be less convincing; for it is possible, although not probable, that two writers might show identical characteristic curves.

With this conclusion the matter remained for more than ten years. On innumerable occasions it was suggested that the process ought to be applied to an examination of the writings of Bacon and Shakespeare with a view of forever settling a controversy which will doubtless forever remain unsettled. This, of course, had been all along in view, but it involved an expenditure of time and labor in letter and word counting quite beyond what might be expected from individual en-

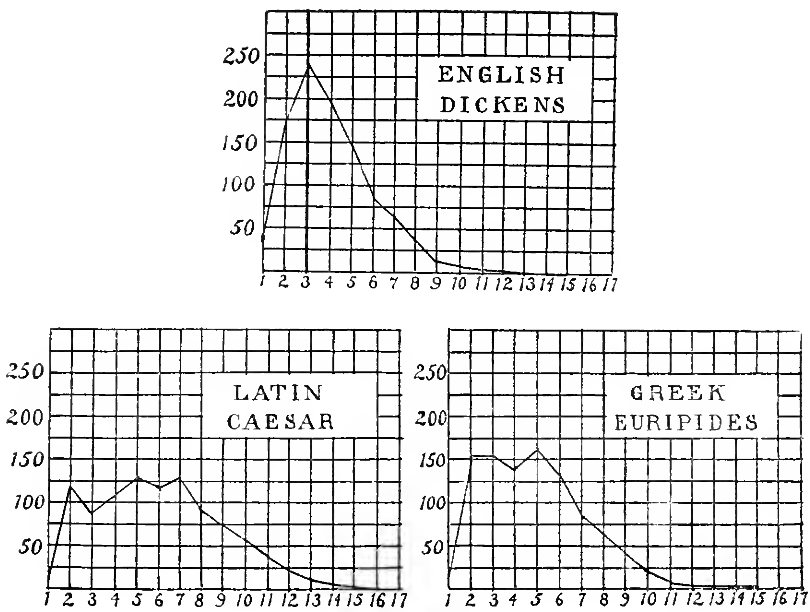


FIG. 3.

thusiasm. The operation is not one of thrilling interest, and volunteer assistance could not be depended upon when the number of things to be counted and classified grew into millions.

That the method has been applied at last to this most curious and yet most interesting question is entirely due to the liberality of Mr. Augustus Heminway, of Boston, who kindly offered to defray the expenses of the work, that is, to employ persons to count and classify nearly two millions of words. Besides expressing my indebtedness to Mr. Heminway, I wish to make grateful acknowledgment of the ex-

cellent and entirely satisfactory manner in which the heavy task of counting was performed by the ladies who undertook it, Mrs. Richard Mitchell and Miss Amy C. Whitman, of Worcester, Massachusetts. Their intelligent interest in the problem itself, together with their excellent knowledge of the various authors under examination and familiarity with the literature of the Shakespearean period, contributed greatly to the easy accomplishment of the work. The operation of counting was greatly facilitated by the construction of a simple counting machine by which a registration of a word of any given number of letters was made by touching a button marked with that number. One of the counters, with book in hand, called off 'five,' 'two,' 'three,' etc., as rapidly as possible, counting the letters in each word carefully and taking the words in their consecutive order, the other registering, as called, by pressing the proper buttons. Practice enabled the counters to do the work with remarkable rapidity, so that, although they were occupied for several months, the total time required was really only about one-quarter of the original estimate. The work was very exhausting, however, and could not be kept up satisfactorily more than three to five hours each day. After some preliminary work the counting of Shakespeare was seriously begun, and the result from the start with the first group of a thousand words was a decided surprise. Two things appeared from the beginning: Shakespeare's vocabulary consisted of words whose average length was a trifle below four letters, less than that of any writer of English before studied; and his word of greatest frequency was the *four-letter* word, a thing never met with before. His preference for the four-letter word may be said, indeed, to constitute the striking characteristic of his composition. At first it was thought that it might be a general characteristic of the English of his time, but that was found to be not the case. Its appearance in the composition of one or two of his contemporaries will be considered presently. Altogether about 400,000 words of Shakespeare were counted and classified, including, in whole or in part, nearly all of his most famous plays. His 'characteristic curve' is most persistent, that based on the first 50,000 words differing very little from that of the whole count. Two groups have been formed by combining alternate small groups (single plays or parts of plays) in a purely mechanical way, so as to include as nearly as may be the same number of words in each. The curves corresponding to them are plotted in Fig. 4, where, however, the differences have been of necessity somewhat exaggerated in order to make them show at all. The practical identity of these curves must be regarded as convincing evidence of the soundness of the original assumption. Not all of the Shakespeare count was completed at one time; other authors were taken up, and it is worth noting that the counters declared their ability to recognize Shakespeare by the mere 'run of words' without

knowing what book or author was in hand, more especially on account of the exceptional excess of four-letter words.

The characteristic curve of Bacon was developed along with that of Shakespeare and was based on his 'Henry VII.,' the 'Advancement of Learning' and a large number of his shorter essays, the total number of words being nearly 200,000.

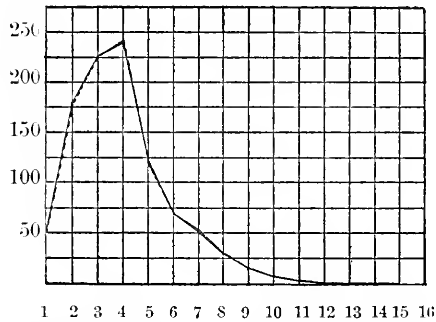


FIG. 4. SHAKESPEARE—TWO GROUPS, ABOUT 200,000 WORDS EACH.

Besides these, extensive counting was done from the writings of Ben Jonson, Addison, Milton, Beaumont and Fletcher, Christopher Marlowe, Goldsmith and Lord Lytton and small groups from a few more modern authors. It is possible, here, to give only general conclusions and to exhibit the diagrams of the more important and interesting results.

One of the first questions likely to be raised is, when an author writes both prose and poetry, will the two styles of composition follow the same general law and show the same characteristic curves? Unfortunately it is not possible to answer this as completely as could be desired, as no one has written enough in two or more different styles, as prose, poetry, history, essay, drama, etc., to produce normal characteristic diagrams. Several of the authors above named were examined with this point in view, and while some of them exhibited somewhat different curves in play writing and in essay or serious prose composition in every case any marked peculiarity found in one style was also found in the other. A good example of this is shown in the two Shakespeare curves of Fig. 5. The continuous line is based on his 'Rape of Lucrece' and 'Venus and Adonis,' while the broken line is his normal curve in play writing.

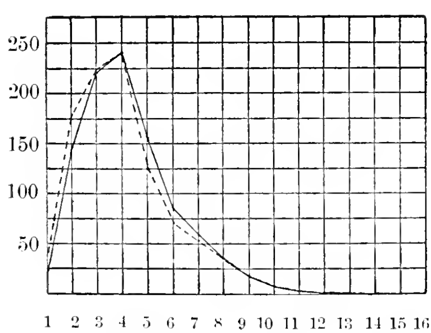


FIG. 5. SHAKESPEARE ——— POETRY ...... PROSE.

It will be noted that the Shakespearean peculiarity of an excessive use of four-letter words is shown in the same degree in both and that while there are apparent differences of considerable magnitude the curves are really strikingly alike, every bend in one having a correspond-

ing flexure in the other. This is typical of all comparisons of different styles of composition by the same author. Undoubtedly there will always be found differences in the graphic representations of serious prose compositions and those of a higher vein, poetry or play, by the same writer, but the evidence at hand goes to show that the leading personal peculiarities of composition will invariably be found in both.

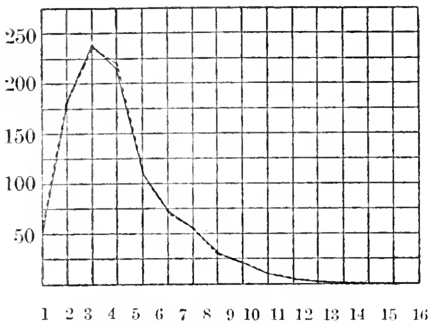


FIG. 6. TWO GROUPS, BEN JONSON.

Fig. 6 shows the curves of two groups of about 75,000 words each from the plays of Ben Jonson, the most notable literary contemporary of Shakespeare. Their close agreement is another very satisfactory confirmation of the fundamental principle and their difference from the Shakespearean curve is striking. It will be observed that Jonson follows the usual practice of making use of the three-letter word most frequently.

Fig. 7 shows the characteristic curves of Bacon and Shakespeare side by side and may be regarded, perhaps, as the objective point of the entire investigation. The reader is at liberty to draw any conclusions he pleases from this diagram.

Should he conclude that, in view of the extraordinary differences in these lines, it is clear that Bacon could not have written the things ordinarily attributed to Shakespeare, he may yet, possibly, be willing to admit that, in Mr. Heminway's own words, 'the question still remains, who did?' Assuming this question to be a reasonable one, the method now under consideration can never do more than direct inquiry or suspicion.

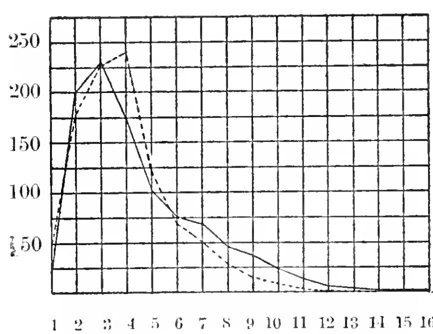


FIG. 7. ——— BACON ...... SHAKESPEARE.

During the progress of the count it seemed as if the Shakespearean peculiarity of the excessive use of words of four letters was unique, that no other writer would be found with this characteristic. On working out the results of a very extensive count of the plays of Beaumont and Fletcher, however, it was found that on the final average the num-

ber of four-letter words was slightly greater than that of three letters, although the excess was by no means so persistent in small groups. The curve of their composition is, on the whole, quite like that of Shakespeare. The lack of persistency of form among small groups may be accounted for by the fact that the work is in a large, though unknown, degree a joint product. The comparison with Shakespeare is shown in Fig. 8.

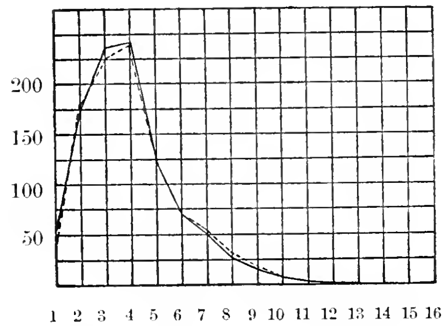


FIG. 8.——BEAUMONT AND FLETCHER ...... SHAKESPEARE.

It was in the counting and plotting of the plays of Christopher Marlowe, however, that something akin to a sensation was produced among those actually engaged in the work. Here was a man to whom it has always been acknowledged, Shakespeare was deeply indebted; one of whom able critics have declared that he 'might have written the plays of Shakespeare.' Indeed a book has been only recently published to prove that he did write them. Even this did not lessen the interest with which it was discovered that in the characteristic curve of his plays Christopher Marlowe agrees with Shakespeare about as well as Shakespeare agrees with himself, as is shown in Fig. 9. Finally, an interesting incident developed in an examination of a bit of dramatic composition by Professor Shaler, of Harvard University, entitled 'Armada Days.' It was a brochure of only about twenty thousand words, printed for private circulation, in which the author had endeavored to compose in the spirit and style of the Elizabethan Age. Although too small to produce anything like a 'normal' curve it was counted and plotted, and the diagram indicated that Professor Shaler had not only caught the spirit of the literature of the time, but that he had also unconsciously adopted the mechanism which seems to characterize it. In the excess of the four-letter word and in other respects the curve was rather decidedly Shakespearean, although it was written before its author knew anything of such an analysis as this.

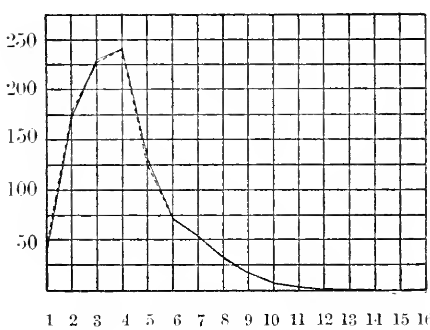


FIG. 9.——MARLOWE ..... SHAKESPEARE.

THE IMPORTANCE OF GENERAL STATISTICAL IDEAS.*

BY SIR ROBERT GIFFEN, K.C.B., LL.D., F.R.S.

I TRUST you will excuse me, on an occasion like the present, for returning to a topic which I have discussed more than once—the utility of common statistics. While we are indebted for much of our statistical knowledge to elaborate special inquiries, such as were made by Mr. Jevons on prices and the currency, or have lately been made by Mr. Booth into the condition of the London poor, we are indebted for other knowledge to continuous official and unofficial records, which keep us posted up to date as to certain facts of current life and business, without which public men and men of business, in the daily concerns of life, would be very much at a loss. What seems to me always most desirable to understand is the importance of some of the ideas to be derived from the most common statistics of the latter kind—the regular records of statistical facts which modern societies have instituted, especially the records of the census, which have now existed for a century in most European countries and among peoples of European origin. Political ideas and speculation are necessarily colored by ideas originating in such records, and political action, internationally and otherwise, would be all the wiser if the records were more carefully observed than they are, and the lessons to be derived widely appreciated and understood.

I propose now to refer briefly to one or two of these ideas which were taken up and discussed on former occasions,† and to illustrate the matter farther by a reference to one or two additional topics suggested in the same manner, and more particularly by the results of the last census investigations, which complete in this respect the record of what may be called the statistical century *par excellence*—the century which has just closed.

Increase of European Population during last Century.

The first broad fact then of this kind, which I have discussed on former occasions, is the enormous increase of the population of Eu-

* Address of the President to the Economic Science and Statistics Section of the British Association for the Advancement of Science. Glasgow, 1901.

† Cf. *Essays in Finance*, 2nd series, pp. 275–364, and *Proceedings of Manchester Statistical Society*, October 17, 1900.

ropean countries and of peoples of European origin during the century just passed, especially the increase of the English people and of the United States, along with the comparative stationariness of the population of one or two of the countries, particularly France, at the same time. The growth all round is from about 170 millions at the beginning of the century to about 510 millions (excluding South American countries and Mexico); while the growth of the United States alone is from a little over 5 to nearly 80 millions, and of the English population of the British Empire from about 15 to 55 millions. Germany and Russia also show remarkable growth, from 20 to 55 millions in the one case and from 40 to 135 millions in the other—partly due to annexation; but the growth of France is no more than from 25 to 40 millions. Without discussing it, we may understand that the economic growth is equally if not more remarkable. The effect necessarily is to assure the preponderance of European peoples among the races of the world—to put aside completely, for instance, the nightmares of yellow or black perils arising from the supposed overwhelming mass of yellow or black races, these races by comparison being stationary or nearly so. The increase of population being continuous, unless some startling change occurs before long, each year only makes European preponderance more secure. Equally it follows that the relative position of the English Empire, the United States, Russia and Germany has become such as to make them exclusively the great world powers, although France, for economic reasons, notwithstanding the stationariness of its population, may still be classed amongst them. When one thinks what international politics were only a hundred years ago—how supreme France then appeared; how important were Austria, Italy, Spain, and even countries like Holland, Denmark and Sweden—we may surely recognize that with a comparatively new United States on the stage, and with powers like Russia and Germany come to the front, the world is all changed politically as well as economically, and that new passions and new rivalries have to be considered.

The figures also suggest that for some time at least the movements going on must accentuate the change that has occurred. According to the latest figures, there is no sign that either in France or any other European country which has been comparatively stationary has any growth of population commenced which will reverse the change, while a large increase of population goes on in the leading countries named. This increase, it is alleged, is going on at a diminishing rate—a point to be discussed afterwards—but in the next generation or two there is practically no doubt that the United States will be a larger international factor than it is, both absolutely and relatively, and that Russia, Germany and the English people of the British Empire will also grow, though not in such a way, apparently, as to prevent the greater relative

growth of the United States, and notwithstanding perhaps some relative changes of a minor character amongst themselves.

The foreign nations then with which the British Empire is likely to be concerned in the near future are Russia, Germany and the United States; and other Powers, even France, must more and more occupy a second place, although France, for the moment, partly in consequence of its relations with Russia, occupies a special place.

Special Position of British Empire.

Another idea which follows from a consideration of the same facts is the necessity laid upon the British Empire to consolidate and organize itself in view of the large additions of subject races made to it in the last century, and especially in the last twenty years of the century. In a paper which I read before the Royal Colonial Institute two years ago, an attempt was made to show that the burden imposed on the white races of the Empire by these recent acquisitions was not excessive as far as the prospect of internal tumults was concerned. Relatively to some other Powers, especially France, we have also been gaining internationally in strength and resources. But whether we had gained internationally on the whole, looking at the growth of powers like Russia, the United States and Germany, and their greater activity in world-politics, was a different question. The problem thus stated remains. It would be foreign to the scope of an address like this, which must avoid actual politics, to examine how far light has been thrown on it by the South African war. No one can question at least that the organization of the Empire must be governed by considerations which the international statistics suggest, and that no step can be taken safely and properly unless our public men fully appreciate the ideas of international strength and resources as well as other considerations which are germane to the subject.

Europe and Foreign Food Supplies.

Another idea to which attention may be drawn appears to be the increasing dependence of European nations upon supplies of food and raw material obtained from abroad. We are familiar with a conception of this kind as regards the United Kingdom. For years past we have drawn increasing supplies from abroad, not merely in proportion to the growth of population, but in larger proportion. The position here obviously is that, with the industries of agriculture and the extraction of raw material (except as regards the one article, coal) practically incapable of expansion, and with a population which not only increases in numbers, but which becomes year by year increasingly richer per head, the consuming power of the population increases with enormous

rapidity, and must be satisfied, if at all, by foreign imports of food and raw materials; there is no other means of satisfaction. But what is true of the United Kingdom is true in a greater or less degree of certain European countries—France, the Low Countries, the Scandinavian countries, Austria-Hungary, Italy and Germany. Especially is it true in a remarkable degree of Germany, which is becoming increasingly industrial and manufacturing, and where the room for expansion in agriculture is now very limited. Those interested in the subject may be referred to an excellent paper by Mr. Crawford, read at the Royal Statistical Society of London about two years ago. What I am now desirous to point out is the governing nature of the idea, which necessarily follows from the conception of a European population living on a limited area, with the agricultural and extractive possibilities long since nearly exhausted, and the population all the time increasing in numbers and wealth. Such a population must import more and more year by year, and must be increasingly dependent on foreign supplies.

I shall not attempt to do over again what is done in Mr. Crawford's paper, but a few figures may serve to illustrate what is meant. In the 'Statistical Abstract' for the principal and other foreign countries I find tables for certain European countries classifying the imports for a series of years into articles of food, raw and semi-manufactured articles, etc. From these I extract the following particulars for all the countries which have tables in this form:

Imports of Articles of Food and Raw Materials and Semi-manufactured Articles into the undermentioned Countries in 1888 *and* 1898 *compared.*

	1888	1898	Increase. Amount.	Increase. Per Cent.
		ARTICLES OF FOOD, ETC.		
Russia........1,000 roubles	78,975	105,391	27,416	35
German Empire, mln. marks	907	1,819	912	100
France........1,000 francs	1,503,000	1,505,000	Nil	Nil
Switzerland ... "	238,000	332,000	94,000	40
Italy ....1,000 lire	274,480	391,600	117,120	42
Austria-Hungary, 1,000 gulden	(1891) 108,441	191,919	92,478	85
		RAW AND SEMI-MANUFACTURED MATERIALS.		
Russia.......1,000 roubles	241,497	313,629	71,132	29
German Empire, mln. marks	1,507	2,247	740	49
France........1,000 francs	2,014	2,348	334	16
Switzerland ... "	308,110	390,111	82,001	27
Italy ....1,000 lire	398,330	509,418	111,088	28
Austria-Hungary, 1,000 gulden	231,000	293,000	62,000	27

The drawback to this table is that it is one of values. Consequently the increase of values in the later years may in part be one of values only without corresponding increase of quantities. But the general course of prices in the period in question was not such as to cause a great change of values apart from a change in quantities. The inference seems undeniable, then, that the Continental countries named, especially Germany, have largely increased their imports of food and raw materials of recent years—that is, have become increasingly dependent on foreign and over-sea supplies. The position of Germany, with its enormous increase of food imports—from 907 to 1,819 million Marks, or from 45 to over 90 million sterling, and its corresponding increase of raw material imports—from 1,507 to 2,247 million Marks, or from 75 to 112 million sterling—is especially remarkable.

An examination in detail of the quantities imported of particular articles would fully confirm the impression given by the summary figures. But it may be enough to refer to the 'Statistical Abstract' from which I have been quoting, as well as to Mr. Crawford's paper. The figures are not out of the way in any respect, and it is the idea we have now to get hold of.

The inference is that the difference between the United Kingdom and Continental countries, especially Germany, as regards dependence on foreign supplies of food and raw materials, is only one of degree, and that as regards Germany at least, the conditions are already remarkably like those of the United Kingdom, while the more rapidly Germany increases its manufacturing and industrial population, the more like it will become to this country. In other words, in the future there will be two great countries, and not one only, dependent largely for their food and raw materials on supplies from abroad. What their position is to be economically and otherwise relatively to the United States, which is at once the main source of supply and a competitor with European countries in manufactures, is obviously a matter of no little interest. As a believer in free trade, I am sure that nothing but good will come to all the countries concerned if trade is interfered with as little as possible by tariffs and government regulations. I believe, moreover, that the practice of free trade, whatever their theories may be, will unavoidably be accepted by all three countries before long. Obviously, however, as the new tariff in Germany indicates, there is to be a great struggle in that country before the situation is accepted; and if some people in this country had their way, notwithstanding our long experience of free trade and its blessings, we should even have a struggle here.

There is another point of view from which the facts should be studied. We are accustomed, and rightly so, I think, to consider naval

preponderance indispensable to the safety of the Empire, and especially indispensable to the safety of the country from blockade, and from the interruption of its commerce, which would be our ruin. But our position in this respect is apparently not quite exceptional. Less or more our Continental neighbors, and especially Germany, are in the same boat. In the event of war, if they could not make up the loss by traffic over their land frontiers, they would be just as liable to suffer from blockade and interrupted commerce as we are. It is conceivable, moreover, that in certain wars some of the countries might not be able to make up by traffic over their land frontiers for blockade or interruption of commerce by sea. We may apprehend, for instance, that Germany, if it were victorious by sea in a war with France, would insist upon Belgium and Holland on one side, and Italy and Spain on the other side, not supplying by land to France what had been cut off by sea. One or more of these countries might be allies with Germany from the first. Contrariwise France and Russia, if at war with Germany and the Triple Alliance, might practically seal up Germany if they were successful at sea, insisting that the Scandinavian countries and Holland should not make up to Germany by land what had been cut off by sea. Germany in this view, apart from any possibility of rupture with this country, has a case for a powerful fleet. It is not quite so much liable to a blockade as we are, but there is a liability of the same kind. The question of naval preponderance among rival powers may thus become rather a serious one. If preponderance is to be nearly as essential to Germany as it is to this country, who is to preponderate? What our practical action ought to be in the premises is a question that might easily lead us too far on an occasion like this, but the facts should be ever present to the minds of our public men. We may be quite certain that they are quite well known and understood in the councils of the Russian, German, French and other Continental Governments.

New Population and New Markets.

Another idea suggested by the facts appears to be an answer to the question as to how new markets are to be found for the products of an increasing population—a question which vexes the mind of many who see in nothing but foreign trade an outlet for new energies. The point was mentioned in my address at Manchester a year ago, but it deserves, perhaps, a more elaborate treatment than it was possible then to give it. What we see then is that not only in this country, but in Germany and other Continental countries, millions of new people are, in fact, provided for in every ten years, although the resources of the country in food and raw materials are generally used to the full extent, and not capable of farther expansion, so that increasing supplies of food and

raw material have to be imported from abroad. How is the thing done? Obviously the main provision for the wants of the new people is effected by themselves. They exchange services with each other, and so procure the major part of the comforts and luxuries of life which they require. The butcher, the baker, the tailor, the dressmaker, the milliner, the shoemaker, the builder, the teacher, the doctor, the lawyer, and so on, are all working for each other the most part of their lives, and the proportion of exchanges with foreign countries necessary to procure some things requirèd in the general economy may be very small. These exchanges may also very largely take the form of a remittance of goods by foreign countries in payment of interest on debts which they owe, so that the communities in question obtain much of what they want from abroad by levying a kind of rent or annuity which the foreigner has to pay. If more is required, it may be obtained by special means, as, for instance, by the working of coal for export, which gives employment in this country to about 200,000 miners, by the employment of shipping in the carrying trade, by the manufacture of special lines of goods, and so on. But the main exchanges of any country are, and must be, as a rule, at home, and the foreign trade, however important, will always remain within limits, and bearing some proportion to the total exchanges of the country. Hence, when additions to the population, and how they are to live, are considered, the answer is that the additions will fill up proportionately the framework of the various industries already in existence, or the ever-changing new industries for home consumption which are always starting into being. These are the primary outlets for new population even in old countries like the United Kingdom and Germany. Of course, active traders and manufacturers, each in their own way, are not to take things for granted. They must strive to spread their activities over foreign as well as over home markets. But looking at the matter from the outside, and scientifically, it is the home and not the foreign market which is always the more important.

The same may be said of a country in a somewhat different economic condition from England and Germany, viz., the United States. I can only refer to it, however, in passing, as the facts here are not so clearly on the surface. Contrary to England and Germany, which have no food resources and resources of raw material capable of indefinite expansion, the United States is still to a large extent a virgin country. Its increasing population is therefore provided for in a different way for the most part from the increase in England and Germany. But even in the United States it has been noticeable at each of the last census returns that the increasing population finds an outlet more and more largely, not in agriculture and the extraction of raw materials, but in the miscellaneous pursuits of industry and manufacture. The town population

increases disproportionately. In the last census especially it was found that the overflow of population over the far Western States seemed to have been checked, the increase of population being mainly in the older States and the towns and cities of the older States. The phenomena in England and Germany and in other Continental countries are accordingly not singular. The older countries, and the older parts even of a new country like the United States are becoming more and more the centers where populations live and grow, because they are the most convenient places for the general exchange of services with each other among the component parts of a large population, which constitutes production and consumption. A small expenditure of effort in proportion enables such communities to obtain from a distance the food and raw materials which they require. Migration is no longer the necessity that it was.

Decline in Rate of Growth of Population.

I come now to another idea appearing on the surface of the census returns when they are compared for a long time past, and the connected returns of births, marriages and deaths, which have now been kept in most civilized communities for generations. Great as the increase of population is with which we have been dealing, there are indications that the rate of growth in the most recent census periods is less in many quarters than it formerly was, while there has been a corresponding decline in the birth-rates; and to some extent, though not to the same extent, in the rate of the excess of births over deaths, which is the critical rate of course in a question of the increase of population. These facts have suggested to some a question as to how far the increase of population which has been so marked in the past century is likely to continue, and speculations have been indulged in as to whether there is a real decline in the fecundity of population among the peoples in question resembling the decline in France, both in its nature and consequences. I do not propose to discuss all these various questions, but rather to indicate the way in which the problem is suggested by the statistics, and the importance of the questions thus raised for discussion, as a proof of the value of the continuous statistical records themselves.

The United States naturally claims first attention in a matter like this, both on account of the magnitude of the increase of population there, and the evidence that recent growth has not been quite the same as it was earlier in the century. Continuing a table which was printed in my address as president of the Statistical Society, in 1882, above referred to, we find that the growth of population in the United States since 1800 has been as follows in each census period:

Population in the United States, and Increase in each Census Period of the Nineteenth Century.

Year.	Population.	Increase since Previous Census.	
		Amount.	Per Cent.
	Millions.	Millions.	
1800	5.3	—	—
1810	7.2	1.9	36
1820	9.6	2.4	33
1830	12.9	3.3	34
1840	17.1	4.2	33
1850	23.2	6.1	36
1860	31.4	8.2	36
1870	38.5	7.1	23
1880	50.1	11.6	30
1890	62.6	12.5	25
1900	75.7*	13.1	21

Thus it is quite plain that something has happened in the United States to diminish the rate of increase of population after 1860. Up to that time the growth in each census period from 1800 downwards had ranged between 33 and 36 per cent. Since then the highest rates have been 30 per cent. between 1870 and 1880 and 25 per cent: between 1880 and 1890. There is a suspicion, moreover, that, owing to errors in the census of 1870, which were corrected in 1880, the increase between 1870 and 1880 was not quite so high as stated. There is accordingly a somewhat steep decline from a growth in each ten years prior to 1860, ranging between 33 and 36 per cent., to a growth first of about 25 per cent., and finally of 21 per cent. only. The Civil War of the early sixties naturally occurs to one as the explanation of the break immediately after 1860, but the effects could hardly have continued to the present time, and a more general explanation is suggested.

Other special explanations have occurred to me as partly accounting for the change. One is that, prior to 1860, the United States at different times increased its territory and population partly by purchase and partly by annexation. But I cannot make out that either the purchase of Louisiana early in the century, or the subsequent annexations following the Mexican war, would make a material difference. There is a considerable increase certainly after the Mexican war, but it would be difficult indeed to estimate how much of the population of Texas and New Mexico, which was then added to the Union, had previously swarmed over from the Union, and had thus been from the first economically, if not politically, part of the United States. Another obvious suggestion is that possibly immigration into the United States

* This does not include population of Indian reservation, etc., now included in the official census for the first time.

has fallen off as compared with what it formerly was. But this explanation also fails, as far as the official figures carry us. The proportion of immigration to the total increase of population in each census period since 1820, previous to which I have not been able to obtain figures, has been as follows:

Proportion of Immigration to Total Increase of Population in the undermentioned Periods in the United States.

	Per Cent.		Per Cent.
1820–30	4.7	1860–70	35.0
1830–40	14.2	1870–80	24.2
1840–50	27.9	1880–90	42.1
1850–60	31.5	1890–1900	29.4

Immigration, according to these figures, has thus in late years played as important a part as it formerly did in the increase of population in the United States. Possibly the official figures of immigration of late years are a little exaggerated, as the United States Government does not show a balance between immigration and emigration; but whatever corrections may be made on this account, the recent figures of immigration are too large to permit the supposition that the failure of immigrants accounts in the main for the diminished rate of increase of the population generally. The ten years' percentage of increase without immigrants, I may say, varied before 1860 between 24 and 32 per cent., and has since fallen to 14 and 15 per cent. Even if the latter figures should be increased a little to allow for the overestimate of immigration, the change would be enormous.

Passing from the United States, we meet with similar phenomena in Australasia. Indeed, what has happened in Australasia of late has been attracting a good deal of attention. The following short table, which is extracted from the statistics of Mr. Coghlan, the able statistician of the Government of New South Wales, gives an idea of what has occurred:

Population of Australasia at different Dates, with the Annual Increase Per Cent. in each Period.

	Population.	Annual Increase Per Cent. since Previous Date.		Population.	Annual Increase Per Cent. since Previous Date.
	Thousands.			Thousands.	
1788	1.0	—	1851	430.6	7.36
1801	6.5	15.13	1861	1,253.0	11.30
1811	11.5	11.94	1871	1,924.8	4.39
1821	35.6	5.88	1881	2,742.5	3.60
1831	79.3	8.34	1891	3,809.9	3.34
1841	211.1	10.28	1899	4,483.0	2.1

Supplementary Table of Rate per Cent. of Increase since 1890.

	Per Cent.		Per Cent.
1891	3.34	1896	1.84
1892	2.10	1897	1.86
1893	1.96	1898	1.40
1894	1.95	1899	1.44
1895	1.88		

The decline in the rate of increase is so great and palpable as to need no comment.

Here the perturbations due to immigration have obviously been greater than in the case of the United States. The country was, in fact, settled mainly between 1850 and 1870, without previously having had a population to speak of. But deducting immigration, the increase would appear to have been as follows in each decade:

Rate of Increase Per Cent. of Population in Australasia, deducting Immigration, in the undermentioned Periods.

	Per Cent.		Per Cent.
1851–60	48.5	1880–90	24.5
1860–70	30.0	1890–99	16.0
1870–80	25.0		

Of course, so long as immigration continues, the effect is to swell indirectly the natural increase of population, so that the large increases here shown between 1851 and 1870, and even down to 1890, may be accounted for in part as the indirect result of the large immigration that was going on. But whatever the cause, the fact is unmistakable that the rate of increase, apart from the direct immigration, has declined just as it has done in the United States.

There has been a similar though not nearly so marked a decrease in England, at any rate if we carry the comparison back to the period before 1850. The population at each census period since 1800 in England, with the percentage increase between each census period, has been as follows:

Population of England at the Date of each Census since 1800 with Percentage of Increase between each Census.

Year.	Population.	Increase Per Cent. Since Previous Census.	Year.	Population.	Increase Per Cent. Since Previous Census.
	Millions.			Millions.	
1800	8.9	—	1860	20.1	11.9
1810	10.2	14.0	1870	22.7	13.2
1820	12.0	18.1	1880	26.0	14.4
1830	13.9	15.8	1890	29.0	11.6
1840	15.9	14.5	1900	32.3	12.2
1850	17.9	12.9			

Thus the increase between recent census periods has been sensibly less than it was before 1850; and the slight recovery between 1860 and 1880 has not been maintained. We are thus in presence of much the same kind of change as has been shown in the United States and in Australasia.

It should be noted, however, in order that we may not strain any fact, that, when the United Kingdom is viewed as a whole, Scotland

and Ireland, as well as the senior partner, being taken into account, it cannot be said that there is any falling off in the rate of growth of the population since 1850. For several decades after that, in fact, the rate of growth of the United Kingdom as a whole was diminished enormously by the emigration from Ireland, and the growth since 1860 has been at a greater rate than in the thirty years before. There may be new causes at work which will again diminish the rate of growth, but in a broad view they do not make themselves visible owing to the disturbance caused by the Irish emigration. Still the facts as to the United Kingdom as a whole ought not to prevent us from considering the facts respecting England only along with the similar facts respecting the United States and Australasia.

These diminutions in the rate of growth of large populations, as I have indicated, are corroborated by a study of the birth-rates, and of the rate of the excess of births over deaths.

The United States unfortunately is without birth- or death-rates, owing to the want of a general system of registration over the whole country. This is a most serious defect in the statistical arrangements of that great country, which it may be hoped will be remedied in time. In the absence of the necessary records I have made some calculations so as to obtain a figure which may be provisionally substituted for a proper rate of the excess of births over deaths, which I submit for what it may be worth as an approximation, and an approximation only. In these calculations one-tenth of the increase of population between two census periods, apart from immigration, is compared with the mean of the population at the two census dates themselves, with the following results:

Approximate Rate of Excess of Births over Deaths in the United States, calculated from a Comparison of One-tenth the Increase of Population between the Census Periods, deducting Immigrants, with the Mean of the Numbers of the Population at the two Census Dates.

Year.	1 Population.	2 Mean of Population Between Two Censuses.	3 One-tenth of Increase Since Previous Census, Less Immigrants.	4 Calculated Excess of Births Over Deaths per 1,000, Proportion of Col. 3 to Col. 2.
	Millions.	Millions.	Thousands.	
1800......	5.3	—	—	—
1810......	7.2	6.2	—	—
1820......	9.6	8.4	—	—
1830......	12.9	11.2	308	28
1840......	17.1	15.0	360	24
1850......	23.2	20.1	441	22
1860......	31.4	27.3	565	21
1870......	38.5	35.0	462	13
1880......	50.2	44.4	878	20
1890......	62.6	56.4	722	13
1900......	75.7	69.2	923	13

Thus, while the excess rate was as high as 21 to 28 per 1,000 before 1860, it has since fallen to one of 13 only, or about one-half. Whatever validity may attach to the method of calculation, the real facts would no doubt show a change in the direction of the table—a decline in the rate of the excess of births over deaths from period to period. The decline in the growth of population is thus not merely the direct effect of a change in immigration, but is connected with the birth- and death-rates themselves, although these rates are of course indirectly affected by the amount and proportion of immigration. It would be most important to know what the decline in the birth-rate is by itself, and how far its effects on the growth of population have been mitigated or intensified by changes in the death-rate; but United States records generally give no help on this head.

Dealing with Australasia in the same way, we have the advantage of a direct comparison of both birth- and death-rates and the rate of the excess of births over deaths. This is done in the following table:

Birth-rate and Death-rate and Rate of Excess of Births over Deaths in Australasia for undermentioned Years.

[From Mr. Coghlan's Statistics.]

	Birth-rate.	Death-rate.	Excess of Births Over Deaths.
1861–65	41.92	16.75	25.17
1866–70	39.84	15.62	24.22
1871–75	37.34	15.26	22.08
1876–80	36.38	15.04	21.34
1881–85	35.21	14.79	20.42
1886–90	34.43	13.95	20.48
1891–95	31.52	12.74	18.78
1896–99	27.35	12.39	14.96

Thus from a high birth-rate forty years ago Australasia has certainly gone down to very ordinary birth-rates, lower than in the United Kingdom and in Continental countries, and Australasia certainly has had heavy declines in the rate of excess of births over deaths, viz., from 25.17 in 1861–65 to 15 in 1896–99, which is to be compared with the decline in the United States, as above stated approximately, from 28 in 1820–30, and 21 as late as 1860, to 13 in the last twenty years.

A similar table for England only gives the following results:

Birth-rate and Death-rate and Rate of Excess of Births over Deaths in England for undermentioned Years.

	Birth-rate per 1,000.	Death-rate per 1,000.	Excess of Birth-rate Over Death-rate.
1851	34.2	22.0	12.2
1861	34.6	21.6	13.0
1871	35.0	22.6	12.4
1881	33.9	18.9	15.0
1891	31.4	20.2	11.2
1899	29.3	18.3	11.0

Note.—Highest birth-rate in 1876, 36.3.

Here the birth-rates, to begin with, are not so high as in Australasia, and presumably in the United States, and the excess of births over deaths, though it has declined a good deal since 1871–81, when it was highest, has been by comparison fairly well maintained, being still 11 per 1,000, as compared with 12.2 in 1851.

We have thus on one side a manifest decline in the rate of growth of population in three large groups of population, coupled with a large decline of birth-rates in England and Australasia where the facts are known, and a smaller decline in the rate of the excess of births over deaths, this decline in England as yet being comparatively small. Such facts cannot but excite inquiry, and it is an excellent result of the use of continuous statistical records that the questions involved can be so definitely raised.

As I have stated, it would be foreign to the object of this paper to discuss fully the various questions thus brought up for discussion, but one or two observations may be made having regard to some inferences which are somewhat hastily drawn.

1. The rate of growth of population of the communities may still be very considerable, even if it is no higher than it has been in the last few years. A growth of 16, 15, or even 12 per cent. in ten years, owing to the excess of births over deaths, is a very considerable growth, though it is much less than the larger figures which existed in some parts forty or fifty years ago. What has happened in the United Kingdom is well worth observing in this connection. Since 1840 the population of the United Kingdom as a whole has increased nearly 60 per cent., although the increase in most of the decades hardly ever exceeded 8 per cent., and in 1840–50 was no more than 2½ per cent. The increase, it must be remembered, goes on at a compound ratio, and in a few decades an enormous change is apparent. The increase from about 170 to 510 millions in the course of the last century among European people generally, though it includes the enormous growth of the United States in those decades, when the rate of growth was at the highest, also includes the slower growth of other periods, and the slower growths of other countries. An addition of even 10 per cent. only as the average every ten years would far more than double the 500 millions in a century, and an increase to at least 1,500 millions during the century now beginning, unless some great change should occur, would accordingly appear not improbable.

2. Some of the rates of growth of population from which there has been a falling off of late years were obviously quite abnormal. I refer especially to the growth in Australasia between 1850 and 1880, and the growth in the United States prior to 1860. They were largely due to the indirect effect of immigration which has been already referred to.

The population to which immigrants are largely added in a few

years, owing to the composition of the population, has its birth-rates momentarily increased and its death-rates diminished—the birth-rates because there are more people relatively at the child-producing ages, and the death-rates because the whole population is younger, than in older countries. It appears quite unnecessary to elaborate this point. The rates of the excess of births over deaths in a country which is receiving a large immigration must be quite abnormal compared with a country in a more normal condition, while a country from which there is a large emigration, such as Ireland, must tend to show a lower excess than is consistent with a normal condition. This explanation, it may be said, does not apply to England, since it is a country which has not been receiving a large immigration or sending out, except occasionally, a large emigration. England, however, must have been affected both ways by movements of this character. It received undoubtedly a large Irish immigration in the early part of last century, and in more recent periods the emigration in some decades, particularly between 1880 and 1890, appears to have been large enough to have a sensible effect on both the birth-rate and the rate of the excess of births over deaths. This effect would be continued down into the following decade, and the consideration is therefore one to be taken note of as accounting in part for the recent decline in birth-rates in England.

In addition, however, it is not improbable that there was an abnormal increase of population in the early part of last century, due to the sudden multiplication of resources for the benefit of a poor population which had previously tended to grow at a very rapid rate, and would have grown at that rate but for the checks of war, pestilence and famine, on which Malthus enlarges. The sudden withdrawal of the checks in this view would thus be the immediate cause of the singularly rapid growth of population in the early part of last century. It is quite in accordance with this fact that a generation or two of prosperity, raising the scale of living, would diminish the rate of growth as compared with this abnormal development, without affecting in any degree the permanent reproductive energy of the people.

3. It is also obvious that one explanation of the decline in birth-rate, and of the rate of the excess of births over deaths, may also be the greater vitality of the populations concerned, so that the composition of the population is altered by an increase of the relative numbers of people not in the prime of life, so altering the proportion of the people at the child-producing ages to the total. This would be too complex a subject for me to treat in the course of a discursive address. Nor would it explain the whole facts, which include, for instance, an almost stationary annual number of births in the United Kingdom for more than ten years past, notwithstanding the largely increased population. But the case may be one where a great many partial explanations contribute

to elucidate the phenomena, so that this particular explanation cannot be overlooked.

4. There remains, however, the question which many people have rushed in to discuss—viz., whether the reproductive power of the populations in question is quite as great as it was fifty or sixty years ago. We have already heard in some quarters, not merely that the reproductive energy has diminished, but suggestions that the populations in question are following the example of the French, where the rate of increase of the population has almost come to an end. Apart, however, from the suggestions above made as to the abnormality of the increase fifty or sixty years ago, so that some decline now is rather to be expected than not, I would point out that the subject is about as full of pitfalls as any statistical problem can be, for the simple reason that it can only be approached indirectly, as there have been no statistical records over a long series of years showing the proportion of births to married women at the child-producing ages, distinguishing the ages, and showing at the same time the proportion of the married women to the total at those ages. Unless there are some such statistics, direct comparisons are impossible, and a good many of the indirect methods of approaching the subject which I have studied a little appear, to say the least, to leave much to be desired. We find, for instance, that a comparison has been made in Australasia between the number of marriages in a given year or years and the number of births in the five or six years following, which show, it is said, a remarkable decline in the proportion of births to marriages in recent years as compared with twenty or thirty years ago. It is forgotten, however, that at the earlier dates in Australasia, when a large immigration was taking place, a good many of the children born were the children of parents who had been married before they entered the country, while there are hardly any children of such parents at a time when immigration has almost ceased. The answer to such questions is in truth not to be rushed, and the question with statisticians should rather be how the statistics are to be improved in future, so that, although the past cannot be fully explained, the regular statistics themselves will in future give a ready answer.

5. One more remark may, perhaps, be allowed to me on account of the delicacy and interest of the subject. To a certain extent the causes of a decline in reproductive energy may be part and parcel of the improved condition of the population, which leads in turn to an increase of the age at marriage, and an increase of celibacy generally through the indisposition of individual members of the community to run any risk of sinking in the scale of living which they may run by premature marriage. These causes, however, may operate to a great extent upon the birth-rate itself without diminishing the growth of

population, because the children, though born in smaller proportion, are better cared for, and the rate of excess of births over deaths consequently remains considerable, although the birth-rate itself is low. The serious fact would be a decline of the rate of the excess of births over deaths through the death-rate remaining comparatively high while the birth-rate falls. It is in this conjunction that the gravity of the stationariness of population in France appears to lie. While the birth-rate in France is undoubtedly a low one, 21.9 per 1,000 in 1899, according to the latest figures before me, still this would have been quite sufficient to ensure a considerable excess rate of births over deaths, and a considerable increase of population every ten years if the death-rate had been as low as in the United Kingdom—viz., 18.3 per 1,000. A difference of 3.6 per 1,000 upon a population of about 40 millions comes to about 150,000 per annum, or 1,500,000 and rather more every ten years. In France, however, the death-rate was 21.1 per 1,000, instead of 18.3, as in the United Kingdom, and it is this comparatively high death-rate which really makes the population stationary. The speculations indulged in some quarters, therefore, though they may be justified in future, are hardly yet justified by the general statistical facts. The subject is one of profound interest, and must be carefully studied; but the conclusions I have referred to must be regarded as premature until the study has been made.

Conclusion.

Such are a few illustrations of the importance of the ideas which are suggested by the most common statistics—those of the regular records which civilized societies have instituted. It is, indeed, self-evident how important it is to know such facts as the growing weight of countries of European civilization in comparison with others; the relative growth of the British Empire, Russia, Germany and the United States, in comparison with other nations of Europe or of European origin; the dependence of other European countries as well as the United Kingdom upon imports of food and raw materials; the ability of old countries and of old centers in new countries to maintain large and increasing populations; and the evidence which is now accumulating of changes in the rate of growth of European nations, with suggestions as to the causes of the changes. It would be easy, indeed, to write whole chapters on some of the topics instead of making a remark or two only to bring out their value a little. It would also be very easy to add to the list. There was a strong temptation to include in it a reference to the relative growth of England, Scotland and Ireland, which has now become the text of so much discussion regarding the practical question of diminishing the relative representation of Ireland in Parliament, and increasing that of England and Scotland.

It is expedient, however, in an address like this, to avoid anything which verges on party politics, and I shall only notice that while the topic has lately become of keen interest to politicians, it is not new to statisticians, who were able long ago to foresee what is now so much remarked on. This very topic was discussed at length in the addresses of 1882–83, to which reference has been made, and even before that in 1876 it received attention.* Another topic which might have been added is that of the economic growth of the different countries which was discussed in the address in 1883; and such topics as the increase of population in a country like India under the peace imposed by its European conquerors, by which the stationariness of the country in numbers and wealth under purely native conditions has been changed, and something like European progress has been begun. Enough has been said, however, it may be hoped, to justify this mode of looking at statistics, and the ideas suggested by them.

May I once more, then, express the hope, as I have done on former occasions, that as time goes on more and more attention will be given to these common statistics and the ideas derived from them? The domination of the ideas suggested by these common figures of population statistics, in international politics and in social and economic relations, is obvious; and although the decline in the rate of growth of population in recent years, the last of the topics now touched on, suggests a great many points which the statistics themselves are as yet unfit to solve—what *can* be done with a great country like the United States, absolutely devoid of bare records of births, marriages and deaths?—still the facts of the decline as far as recorded throw a great deal of light on the social and economic history of the past century, prepare the way for discussing the further topics which require a more elaborate treatment, and enforce the necessity for more and better records. We may emphasize the appeal then, for the better statistical and economic education of our public men, and for the more careful study by all concerned of such familiar publications as the 'Statistical Abstracts,' the 'Statesman's Year-book,' and the like. The material transformations which are going on throughout the world can be substantially followed without any difficulty in such publications by those who have eyes to see; and to follow such transformations, so as to be ready for the practical questions constantly raised, is at least one of the main uses of statistical knowledge.

* See *Essays in Finance*, 2nd series, p. 290 *et seq.*; p. 330 *et seq.*; and 1st series, p. 280 *et seq.*

THE AIMS OF THE NATIONAL PHYSICAL LABORATORY OF GREAT BRITAIN.*

BY R. T. GLAZEBROOK, F.R.S.,

DIRECTOR OF THE NATIONAL PHYSICAL LABORATORY.

A SPEAKER who is privileged to deliver an experimental lecture from this place is usually able to announce some brilliant discovery of his own, or at least to illustrate his words by some striking experiment. To-night it is not in my power to do this, and I am thereby at a disadvantage. Still I value highly this opportunity which has been given me of making known to this audience the aims and purpose of the National Laboratory.

The idea of a physical laboratory in which problems bearing at once on science and industry might be solved is comparatively new. The Physikalisch-technische Reichsanstalt, founded in Berlin by the joint labors of Werner von Siemens and von Helmholtz during the years 1883–87, was perhaps the first. It is less than ten years since Dr. Lodge, in his address to Section A of the British Association, outlined the scheme of work for such an institution here in England.

Nothing came of this; a committee met and discussed plans, but it was felt to be hopeless to approach the government, and without government aid there were no funds. Four years later, however, the late Sir Douglas Galton took the matter up. In his address to the British Association in 1895 and again in a paper read before Section A, he called attention to the work done for Germany by the Reichsanstalt, and to the crying need for a similar institution in England. The result of this presidential pronouncement was the formation of a committee which reported at Liverpool, giving a rough outline of a possible scheme of organization.

A petition to Lord Salisbury followed, and as a consequence a Treasury committee, with Lord Rayleigh in the chair, was appointed to consider the desirability of establishing a National Physical Laboratory. The committee examined over thirty witnesses and then reported unanimously, "That a public institution should be founded for standardizing and verifying instruments, for testing materials, and for the determination of physical constants." It is natural to turn to the words of those who were instrumental in securing the appointment of this committee and to the evidence it received in any endeavor to dis-

* A discourse delivered at the Royal Institution.

cuss its aims. As was fitting, Sir Douglas Galton was the first witness to be called. It is a source of sorrow to his many friends that he has not lived to see the Laboratory completed.

And here I may refer to another serious loss which in the last few days this Laboratory has sustained. Sir Courtenay Boyle was a member of Lord Rayleigh's committee, and as such was convinced of the need for the laboratory and of the importance of the work it could do. He took an active part in its organization, sparing neither time nor trouble; he intended that it should be a great institution, and he had the will and the power to help. The country is the poorer by his sudden death.

Let me now quote some of Sir Douglas Galton's evidence: "Formerly our progress in machinery," he says, "was due to accuracy of measurement and that was a class of work which could be done as Whitworth showed by an educated eye and educated touch. But as we advance in the applications of science to industry we require accuracy to be carried into matters which cannot be so measured. In the more delicate researches which the physical, chemical and electrical student undertakes he requires a ready means of access to standards to enable him to compare his own work with that of others." Or again: "My view is that if Great Britain is to claim its industrial supremacy, we must have accurate standards available to our research students and to our manufacturers. I am certain that if you had them our manufacturers would gradually become very much more qualified for advancing our manufacturing industry than they are now. But it is also certain that you cannot separate some research from a standardizing department." Then after a description of the Reichsanstalt he continues, "What I would advocate would be an extension of Kew in the direction of the Second Division of the Reichsanstalt with such auxiliary research in the establishment of itself as may be found necessary." The second division is the one which takes charge of technical and industrial questions.

Professor Lodge again gave a very valuable summary of work which ought to be done. Put briefly it was this:

1. Pioneer work.
2. Verification work.
3. Systematic measurements and examination of the properties of substances under all conditions.
4. The precise determination of physical constants.
5. Observational work, testing instruments.
6. Constructional work (gratings, optical glass).
7. Designing new and more perfect instruments.

Such were the views of those who took a prominent part in the founding of the institution.

It is now realized, at any rate by the more enlightened of our leaders of industry, that science can help them. This fact, however, has

been grasped by too few in England; our rivals in Germany and America know it well, and the first aim of the laboratory is to bring its truth home to all, to assist in promoting a union which is certainly necessary if England is to retain her supremacy in trade and in manufacture, to make the forces of science available for the nation, to break down by every possible means the barrier between theory and practice, and to point out plainly the plan which must be followed, unless we are prepared to see our rivals take our place.

"Germany," an American writer,* who has recently made a study of the subject, has said, "is rapidly moving towards industrial supremacy in Europe. One of her most potent factors in this notable advance is the perfected alliance between science and commerce existing in Germany. Science has come to be regarded there as a commercial factor. If England is losing her supremacy in manufactures and in commerce, as many claim, it is because of English conservatism and the failure to utilize to the fullest extent the lessons taught by science, while Germany, once the country of dreamers and theorists, has now become intensely practical. Science there no longer seeks court and cloister, but is in open alliance with commerce and industry." It is our aim to promote this alliance in England, and for this purpose her National Physical Laboratory has been founded.

It is hardly necessary to quote chapter and verse for the assertion that the close connection between science and industry has had a predominant effect on German trade. If authority is wanted I would refer to the history of the anilin dye manufacture, or to take a more recent case, to the artificial indigo industry in which the success of the Badische Company has recently been so marked. The factory at Ludwigshaven started thirty-five years ago with thirty men. It now employs over 6,000, and has on its staff 148 trained scientific chemists. And now when it is perhaps too late the Indian planters are calling in scientific aid and the Indian government is giving some £3,500 a year to investigation.

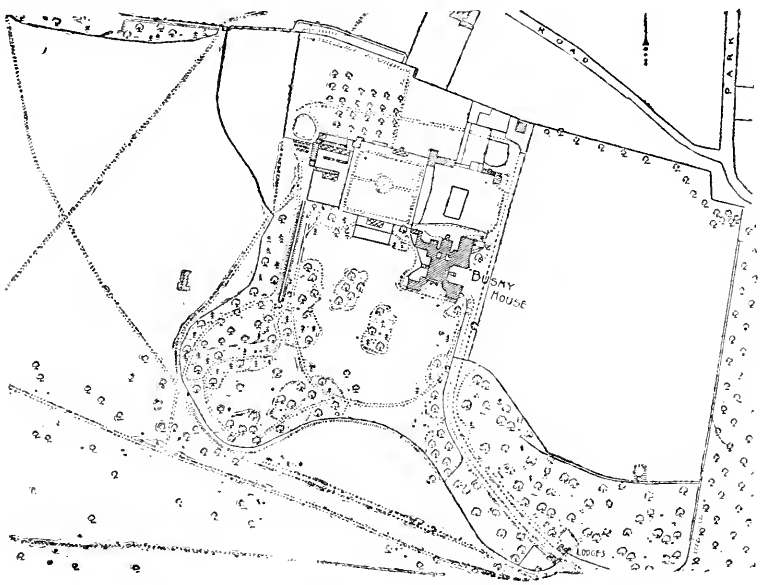
As Professor Armstrong, in a recent letter to the 'Times,' says: "The truly serious side of the matter, however, is not the prospective loss of the entire indigo industry so much as the fact that an achievement such as that of the Badische Company seems past praying for here."

Or, to take another instance, scientific visitors to the Paris Exhibition last year must have been struck by the German exhibit of apparatus. German instrument makers combined to produce a joint exhibit; a strong committee was formed. Under the skilful editorship of Dr. Lindeck of the Reichsanstalt a catalogue was compiled, in which by a judicious arrangement of cross references it was easily

* Professor H. S. Carhart.

possible to find either the exhibit of a particular firm or the apparatus of a particular class. This was printed in German, English and French, and issued freely to visitors. Dr. Drosten, the representative of the exhibitors in charge, or one of his assistants, was ever ready to give information and advice. To one who wished, as I did, to see the most modern forms of German apparatus, the exhibit was a very real help. Let me quote a few lines from the catalogue:

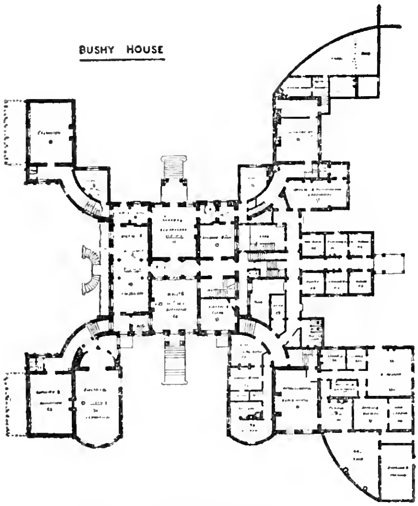
At the commencement of the nineteenth century, the French and English makers of scientific instruments were far in advance of the Germans. True, the eighteenth century had its prominent mechanics in Germany, yet at the



PLAN OF GROUNDS.

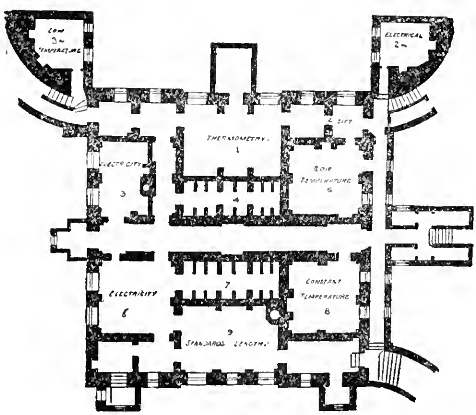
beginning of the nineteenth century French and English makers took the lead, so as to almost supply the world's entire demand in scientific instruments. This predominance had the further consequence of causing young Germans to emigrate to France or England in order thoroughly to master their subject. Many a German mechanic to-day owes to French or English masters a substantial portion of his knowledge. And then in Germany it is only within the last twenty or twenty-five years that the state has espoused the interests of the home industry, but such have been the efforts and the results that the position has at a blow, as it were, changed in favor of Germany. The greatest share of the impetus given to the manufacture of scientific instruments is due to the Reichsanstalt. A characteristic feature of this trade is the unity of its aims, which is traceable to the history of its development and its intimate connection with pure science. During the year 1898 the value of German exports of scientific instruments was about a quarter of a million sterling. It had trebled within ten years; while nearly 14,000 people were employed in it.

And now having stated in general terms the aims of the laboratory and given some account of the progress in general, let me pass to some description of the means which have been placed at our disposal to realize those aims. I here wish, if time permits, to discuss in fuller detail some of the work which it is hoped we may take up immediately.



Bushy House, Ground Plan.

The laboratory is to be at Bushy House, Teddington. I will pass over the events which led to this change of site from the old Deer Park at Richmond to Bushy. It is sufficient to say that at present Kew Observatory in the Deer Park will remain as the observatory department of the laboratory, and most of the important verification and standardization work which in the past has been done there will still find its home in the old building. The house was originally the official residence of the Ranger of Bushy Park. Queen Anne granted it in 1710 to the first Lord Halifax. In 1771 it passed to Lord North, being then probably rebuilt. Upon the death of Lord North's widow, in 1797, the Duke of Clarence, afterwards William IV., became Ranger. After his death in 1837 it was granted to his widow, Queen Adelaide, who lived here until 1849. At her death it passed to the Duc de Nemours, son of King Louis Philippe, and he resided here at intervals until 1896. In spite of this somewhat aristocratic history it will make an admirable laboratory.



Bushy House, Basement.

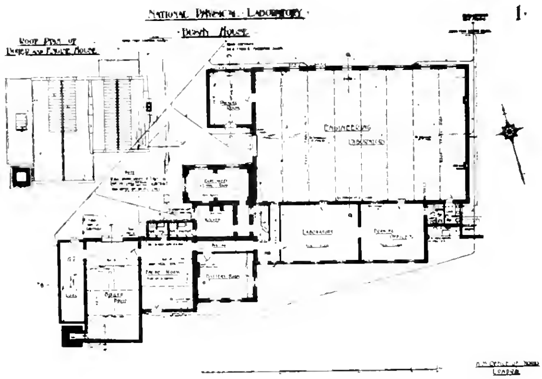
The building is very solid and substantial. There is a good basement under the main central block with roof of brick groining, which makes a very steady support for the floor above.

BUSHY HOUSE, EAST FRONT.

BUSHY HOUSE, SOUTH FRONT

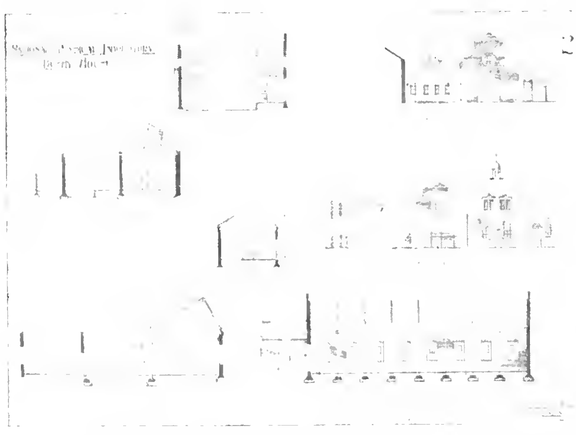
Such is the home of the laboratory. It may be of interest to compare it with the Reichsanstalt.

The floor space available is much less than that of the Reichsanstalt. But size alone is not an unmixed advantage; there is much to be said



ENGINEERING LABORATORY, GROUND PLAN.

in favor of gradual growth and development, provided the conditions are such as to favor growth. Personally I would prefer to begin in a small way, if only I felt sure I was in a position to do the work thoroughly, but there is danger of starvation. Even with all the help we



ENGINEERING LABORATORY, ELEVATIONS AND SECTIONS.

get in freedom from rent and taxes, outside repairs and maintenance, the sum at the disposal of the committee is too small. £14,000 will not build and equip the laboratory. £4,000 a year will not maintain it as it ought to be maintained. Contrast this with the expenditure on the Reichsanstalt or with the proposals in America where the bill

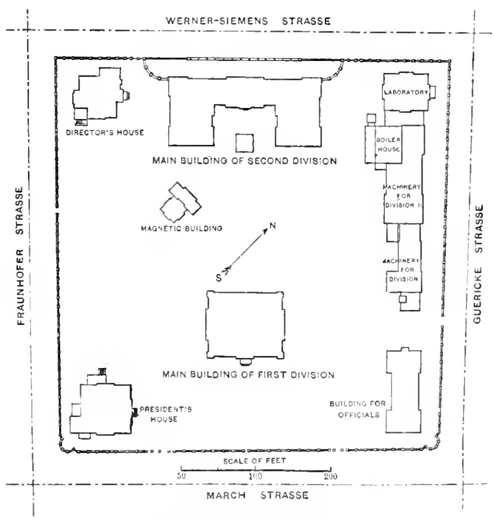
for the establishment of a laboratory has just passed, and an expenditure of £60,000 on building and site and £9,000 a year has been authorized.

CAPITAL EXPENDITURE ON THE REICHSANSTALT.

DIVISION I.		
Site – the Gift of Dr. Siemens	£25,000	
Cost of Buildings	34,275	
Fittings and Furniture	2,700	
Machinery and Instruments	4,100	
		£66,075
DIVISION II.		
Site	£18,600	
Buildings	88,000	
Fittings and Furniture	5,400	
Machinery and Instruments	23,550	
		135,550
		£201,625

ANNUAL EXPENDITURE.

Salaries and Wages	£10,300
Maintenance of Buildings, Apparatus, etc.	6,350
	£16,650



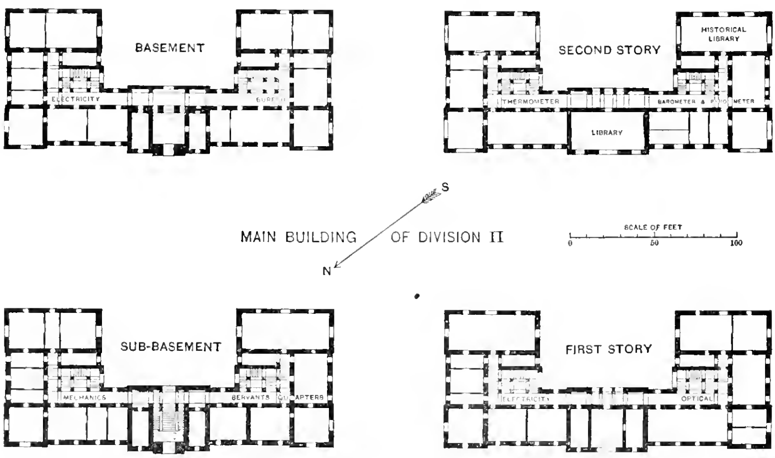
REICHSANSTALT, GENERAL PLAN.

Science is not yet regarded as a commercial factor in England. Is there no one who, realizing the importance of the alliance, will come forward with more ample funds to start us on our course with a fair prospect of success? One real friend has recently told us in print that the new institution is on such a microscopic scale that its utility in the present struggle is more than doubtful. Is there no statesman who can grasp the position and see that, with say double the income,

the chances of our doing a great work would be increased a hundred-fold? The problems we have to solve are hard enough; give us means to employ the best men and we will answer them, starve us and then quote our failure as showing the uselessness of science applied to industry. There is some justice in the criticism of one of our technical papers. I have recently been advertising for assistants, and a paper in whose columns the advertisement appeared writes:

> The scale of pay is certainly not extravagant. It is however possible that the duties will be correspondingly light.

I have thus summarized in a brief manner the aims of the laboratory and have indicated the effect which the application of science to industry has had on one branch of trade in Germany. And now let me illustrate these aims by a more detailed account of some of the problems of industry which have been solved by the application of

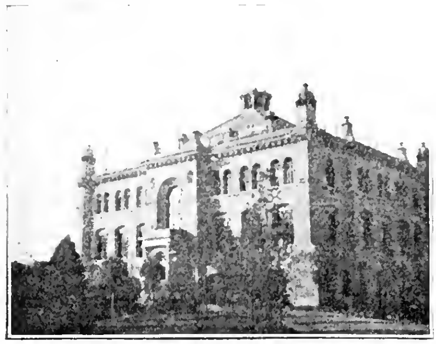


Reichsanstalt, Technical Building.

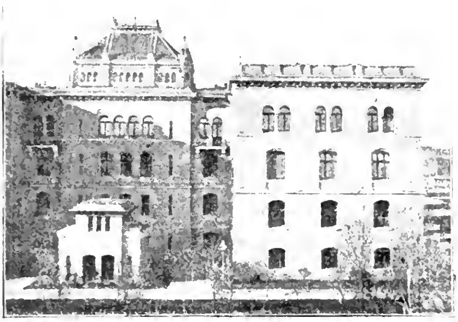
science, and then of some others which remain unsolved and which the laboratory hopes to attack. The story of the Jena glass-works is most interesting; we will take it first.

An exhibition of scientific apparatus took place in London in 1878. Among the visitors to this was Professor Abbé, of Jena, and in a report he wrote on the optical apparatus he called attention to the need for progress in the art of glass-making if the microscope were to advance and to the necessity for obtaining glasses having a different relation between dispersion and refractive index than that found in the material at the disposal of opticians. Stokes and Harcourt had already made attempts in this direction but with no marked success. In 1881 Abbé and Schott at Jena started their work. Their undertaking, they write five years later in the first catalogue of their factory, arose out of a scientific investigation into the connection between the optical proper-

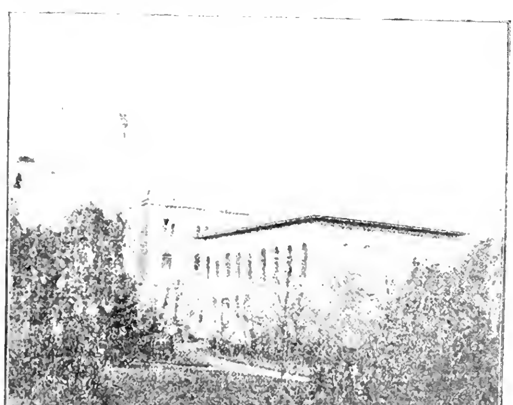
ties of solid amorphous fluxes and their chemical constitution. When they began their work some six elements only entered into the composition of glass. By 1888 it had been found possible to combine with these in quantities up to about 10 per cent. twenty-eight different elements, and the effect of each of these on the refractive index and dispersion had been measured. Thus for example the investigators found that by the addition of boron the ratio of the length of the blue end of the spectrum to that of the red was increased; the addition of fluorine, potassium or sodium produced the opposite result. Now in an ordinary achromatic lens of crown and flint, if the total dispersion for the two be the same, then for the flint glass the dispersion of the blue end is greater; that of the red less than for the crown; thus the image is not white, a secondary spectrum is the result. Abbé showed, as Stokes and Harcourt had shown earlier, that by combining a large proportion of boron with the flint its dispersion was made more nearly the same as that of the crown, while by replacing the silicates in the crown glass by phosphates a still better result was obtained, and by the use of three glasses three



Reichsanstalt, Division I., Main Building.



Reichsanstalt, Division II., Main Building.



Reichsanstalt, Building for Large Currents and Machinery.

lines of the spectrum could be combined. The spectrum outstanding was a tertiary one and much less marked than that due to the original crown and flint glass. The modern microscope became possible.

The conditions to be satisfied in a photographic lens differ from those required for a microscope. Von Seidel had shown that with the ordinary flint and crown glasses the conditions for achromatism and for flatness of field cannot be simultaneously satisfied. To do this we need a glass of high refractive index and low dispersive power or vice versa; in ordinary glasses these two properties rise and fall together. Thus crown glass has a refractive index of 1.518 and a dispersive power of .0166, while for flint the figures are 1.717 and .0339. By introducing barium into the crown glass a change is produced in this respect. For barium crown the refractive index is greater and the dispersive power less than for soft crown. With two such glasses then the field can be achromatic and flat. The wonderful results obtained by Dallmeyer and Ross in this country, by Zeiss and Steinheil in Germany, are due to the use of new glasses. They have also been applied with marked success to the manufacture of the object glasses of large telescopes.

But the Jena glasses have other uses besides optical. "About twenty years ago"—the quotation is from the catalogue of the German Exhibition—"the manufacture of thermometers had come to a dead stop in Germany, thermometers being then invested with a defect, their liability to periodic changes, which seriously endangered German manufacture. Comprehensive investigations were then carried out by the Normal Aichungs Commission, the Reichsanstalt, and the Jena glass works, and much labor brought the desired reward." The defect referred to was the temporary depression of the ice point which takes place in all thermometers after heating. Let the ice point of a thermometer be observed; then raise the thermometer to say 100° and again observe the ice point as soon as possible afterwards; it will be depressed below its previous position; in some instruments of Thuringian glass a depression of as much as 0°.65 C. had been noted. For scientific purposes such an instrument is quite untrustworthy. If it be kept at say 15° and then immersed in a bath at 30° it will be appreciably different from that which would be given if it were first raised to say 50°, allowed to cool quickly just below 30°, and then put into the bath. This was the defect which the investigators set themselves to cure.

DEPRESSION OF FREEZING POINT FOR VARIOUS THERMOMETERS.

Humboldt	1835	0°.06
Greiner	1872	0 .38
Schultzer	1875	0 .44

Rapps	1878	0 .65
English Glass		0 .15
Ver Deer		0 .08
16‴		0 .05
59‴		0 .02

ANALYSIS OF GLASSES.

	SiO_2	Na_2O	CaO	Al_2O_3	ZnO	B_2O_3
16‴	— 67.5	14	7	2.5	7	2
59‴	— 72	11		5		12

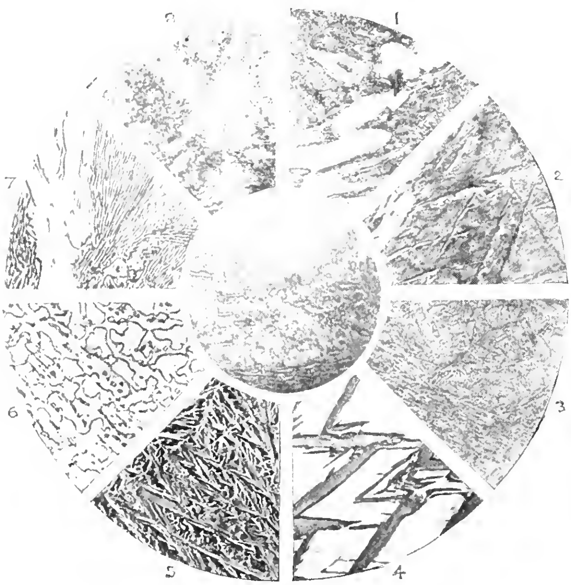
Weber had found in 1883 that glasses which contain a mixture of soda and potash give a very large depression. He made in 1883 a glass free from soda with a depression of 0°.1. The work was then taken up by the Aichungs Commission, the Reichsanstalt, and the Jena factory. Weber's results were confirmed. An old thermometer of Humboldt's containing 0.86 per cent. of soda and 20 per cent. of potash had a depression of 0°.06, while a new instrument, in which the percentages were 12.7 per cent. and 10.6 per cent., respectively, had a depression of 0°.65. An English standard, with 1.5 per cent. of soda, 12.3 per cent. of potash, gave a depression of 0°.15, while a French 'Ver deer' instrument in which these proportions were reversed gave only 0°.08. It remained to manufacture a glass which should have a low depression and at the same time other satisfactory properties. The now well-known glass 16‴ is the result. Its composition is shown in the table. The fact that there was an appreciable difference between the scale of the 16‴ glass and that of the air thermometer led to further investigation, and another glass, a borosilicate, containing 12 per cent. of boron, was the consequence. This glass has a still smaller depression. As a result of this work Germany can now claim that 'the manufacture of thermometers has reached in Germany an unprecedented level and now governs the markets of the world.'

Previous to 1888 Germany imported optical glass; at that date nearly all the glass required was of home manufacture. Very shortly afterwards an export trade in raw glass began, which in 1898 was worth £30,000 per annum, while the value of optical instruments, such as telescopes, field glasses, and the like, exported that year was over £250,000. Such are the results of the application of science, *i. e.*, organized common sense, to a great industry. The National Physical Laboratory aims at doing the like for England.

The question of standardization of patterns and designs is probably too large a one to go into on the present occasion. Some months ago a most interesting discussion of the subject took place at the Institution of Electrical Engineers. To my mind there is no doubt that the judicious adoption of standard types combined with readiness to scrap old patterns, so soon as a real advance or improvement is made, is necessary for progress. One who has been over some good German

workshop or has contrasted a first-class English shop where this is the practice with an old-fashioned establishment where standardization is hardly known, can have no hesitation on this question. It has its disadvantages, less is left to the originality of the workman and in consequence they lose the power of adaptation to new circumstances and conditions. The English mechanic is I believe greatly superior to the German, but the scientific organization of the German shops enables them to compete successfully with the English.

In 1881 the German Association of Mechanics and Opticians was formed, having for its aim the scientific, technical and commercial development of instrument making. The society has its official organ, the 'Zeitschrift für Instrumentenkunde,' edited by one of the staff of



SECTION OF IRON AFTER VARIOUS TREATMENTS.

Specimen.

1. Raised to 1000°. Worked and cooled slowly. Masses of carbide ground work, bands of iron and carbide, *pearlite structure.*

2. Raised to 850° and quickly cooled. Masses disappear.

3. Raised to 850° and quenched in water. Areicular structure. Martensite, hard steel.

4. Raised to 1050° and quenched in iced brine. Martensite and Austenite.

5. Same cooled in liquid air to — 243. Much like martensite.

6. Heated to near melting point, quenched suddenly burnt steel.

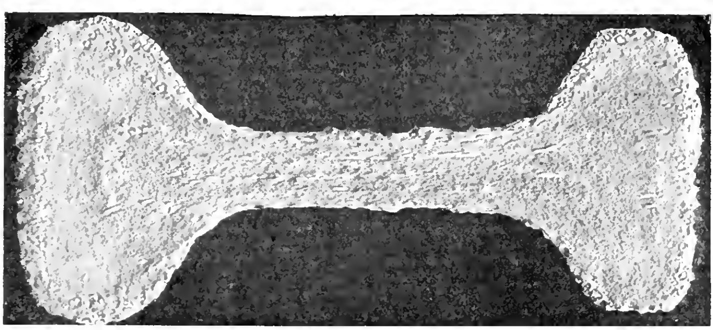
7. Heated to 650°—annealed for a long time at this temperature and slowly cooled, bands of carbide and pearlite.

8. Any specimen except 6 heated to 850, worked and slowly cooled, giving us the structure 1.

Very marked changes might have been produced in 3 by annealing at 140°.

the Reichsanstalt. Specialized schools for the training of young mechanics in the scientific side of their calling have been formed and now the majority of the leading firms retain in their permanent service one or more trained mathematicians or physicists. In this way again the importance of science to industry is recognized. I have thus noted very briefly some of the ways in which science has become identified with trade in Germany, and have indicated some of the investigations by which the staff of the Reichsanstalt and others have advanced manufactures and commerce.

Let us turn now to the other side, to some of the problems which remain unsolved, to the work which our laboratory is to do and by doing which it will realize the aims of its founders. The microscopic examination of metals was begun by Sorby in 1864. Since that date many distinguished experimenters, Andrews, Arnold, Ewing, Martens, Osmond, Roberts-Austen, Stead and others have added much to our knowledge. I am indebted to Sir W. Roberts-Austen for the slides which I am about to show you to illustrate some of the points arrived at. Professor Ewing a year ago laid before the Royal Institution the results of the experiment of Mr. Rosenhain and himself. This microscopic work has revealed to us the fact that steel must be regarded as a crystallized igneous rock. Moreover, it is capable at temperatures far below its melting point of altering its structure completely, and its mechanical and magnetic properties are intimately related to its structure. The chemical constitution of the steel may be unaltered, the amounts of carbon, silicon, manganese, etc., in the different forms remain the same, but the structure changes, and with it the properties of the steel. The figure on page 136 represents sections of the same steel polished and etched after various treatments.

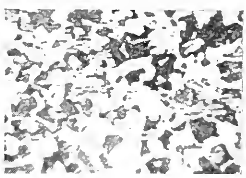


SECTION OF BAD RAIL.

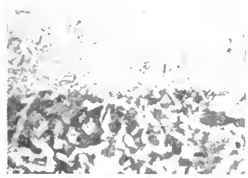
The steel is a highly carbonized form, containing 1.5 per cent. of carbon. If it be cooled down from the liquid state, the temperature being read by the deflexion of a galvanometer needle in circuit with a

thermopile, the galvanometer shows a slowly falling temperature till we reach 1380° C., when solidification takes place. The changes which now go on take place in solid metal. After a time the temperature again falls until we reach 680°, when there is an evolution of heat; had the steel been free from carbon there would have been evolution of heat at 895° and again at 766°. Now throughout the cooling molecular changes are going on in the steel. By quenching the steel suddenly at any given temperature we can check the change and examine microscopically the structure of the steel at the temperature at which it was checked.

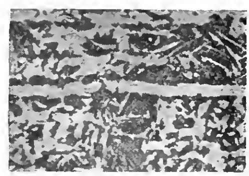
In the figure, with the exception of specimen No. 6, the metal has not been heated above 1050°, over 300° below its melting point.



SECTION OF GOOD RAIL.



SECTION OF BAD RAIL SHOWING SURFACE TO WHICH FRACTURE WAS DUE.



SECTION OF RAIL AFTER ROLLING.

At temperatures between about 900° and 1100° the carbon exists in the form of carbide of iron dissolved in the iron, at a temperature of 890° the iron which can exist in different forms as an allotropic substance passes from the γ form to the β form, and in this form cannot dissolve more than .9 per cent. of carbon as carbide. Thus at this temperature a large proportion of the carbon passes out of the solution. At 680° the remainder of the carbide falls out of the solution as lamina.

Thus the following temperatures must be noted: 1380°, melting point; 1050°, highest point reached by specimen; 890°, .6 per cent. of carbon deposited; 680°, rest of carbide deposited.

To turn now to the details of the photo, the center piece is the cemented steel as it comes from the furnace after the usual treatment.

These slides are sufficient to call attention to the changes which occur in solid iron, changes whose importance is now beginning to be realized. On viewing them it is a natural question to ask how all the other properties of iron related to its structure; can we by special treatment produce a steel more suited to the shipbuilder, the railway engineer or the dynamo maker than any he now possesses?

These marked effects are connected with variations in the condition of the carbon in the iron; can equally or possibly more marked changes be produced by the introduction of some other elements? Guillaume's

nickel steel with its small coefficient of expansion appears to have a future for many purposes; can it by some modification be made still more useful to the engineer?

We owe much to the work of the Alloys Research Committee of the Institution of Mechanical Engineers. Their distinguished chairman takes the view that the work of that committee has only begun and that there is scope for research for a long time to come at the National Physical Laboratory, and the executive committee have accepted this view by naming as one of the first subjects to be investigated the connection between the magnetic quality and the physical, chemical and electrical properties of iron and its alloys with a view specially to the determination of the conditions for low hysteresis and non-aging properties.

At any rate we may trust that the condition of affairs mentioned by Mr. Hadfield in his evidence before Lord Rayleigh's commission which led a user of English steel to specify that before the steel could be accepted it must be stamped at the Reichsanstalt will no longer exist.

The subject of wind pressure again is one which has occupied the committee's attention to some extent.

The Board of Trade rules require for bridges and similar structures (1) that a maximum pressure of 56 pounds per square foot be provided for, (2) that the effective surface on which the wind acts should be assumed as from once to twice the area of the front surface according to the extent of the openings in the lattice girders, (3) that a factor of safety of 4 for the iron work and of 2 for the whole bridge overturning be assumed. These recommendations were not based on any special experiments. The question had been investigated in part by the late Sir Wm. Siemens.

During the construction of the Forth Bridge Sir B. Baker conducted a series of observations.

Table II.

Revolving Gauge Mean Pressure.		Small Fixed Gauge. Easterly.	Small Fixed Gauge. Westerly.	Large Fixed Gauge. Easterly.	Large Fixed Gauge. Westerly.
W.	W.	W.	W.	W.	W.
0 to 5	3.09	3.47	2.92	2.04	1.9
5 to 10	7.58	4.8	7.7	3.54	4.75
10 to 15	12.4	6.27	13.2	4.55	8.26
15 to 20	17.06	7.4	17.9	5.5	12.66
20 to 25	21.0	12.25	22.75	8.6	19
25 to 30	27.0		28.5		18.25
30 to 35	32.5		38.5		21.5
Above	65		41.0		35.25
(One observation only above 32.5.)					

The results of the first two years' observations are shown in Table II. taken from a paper read at the British Association in 1884. Three

gauges were used. In No. 1 the surface on which the wind acted was about $1\frac{1}{2}$ square feet in area; it was swiveled so as always to be at right angles to the wind. In No. 2 the area of surface acted on was of the same size but was fixed with its plane north and south. No. 3 was also fixed in the same direction but it had 200 times the area, its surface being 300 square feet.

In preparing the table the mean of all the readings of the revolving gauge between 0 and 5, 5 and 10, etc., pounds per square foot have been taken and the mean of the corresponding readings of the small fixed gauge and the large fixed gauge set opposite, these being arranged for easterly and westerly winds.

Two points are to be noticed: (1) There is only one reading of over 32.5 pounds registered, and this it is practically certain is due to faulty action in the gauge. Sir B. Baker has kindly shown me some further records with a small gauge.

According to these pressures of over 50 pounds have been registered on three occasions since 1886. On two other occasions the pressures as registered reached from 40 to 50 pounds per square foot. But the table, it will be seen, enables us to compare the pressure on a small area with the average pressure on a large area, and it is clear that in all cases the pressure per square foot as given by the large area is much less than that deduced from the simultaneous observations on the small area.

The large gauge became unsafe in 1896 and was removed, but the observations for the previous ten years entirely confirm this result, the importance of which is obvious. The same result may be deduced from the Tower Bridge observations. Power is required to raise the great bascules and the power needed depends on the direction of the wind. From observations on the power some estimate of the average wind pressure on the surface may be obtained, and this is found to be less than the pressure registered by the small wind gauges.

Nor is the result surprising when the matter is looked at as an hydrodynamical problem—the wind blows in gusts—the lines of flow near a small obstacle will differ from those near a large one; the distribution of pressure over the large area will not be uniform. Sir W. Siemens is said to have found places of negative pressure near such an obstacle. As Sir J. Wolfe Barry has pointed out, if the average of 56 pounds to the square foot is excessive then the cost and difficulty of erection of large engineering works is being unnecessarily increased. Here is a problem well worthy of attention and about which but little is known. The same too may be said about the second of the Board of Trade rules. What is the effective surface over which the pressure is exerted on a bridge? On this again our information is but scanty. Sir B. Baker's experiments for the Forth Bridge led him to adopt as his rule double

the plane surface exposed to the wind and deduct 50 per cent. in the case of tubes. On this point again further experiments are needed.

To turn from engineering to physics. In metrology as in many other Branches of science difficulties connected with the measurement of temperature are of the first importance.

I was asked some little time since to state to a very high order of exactness the relation between the yard and the meter. I could not give the number of figures required. The meter is defined at the freezing point of water, the yard at a temperature of 62° Fahr. When a yard and meter scale are compared they are usually at about the same temperature; the difficulty of the comparison is enormously increased if there be a temperature difference of 30° Fahr. between the two scales. Hence we require to know the temperature coefficients of the two standards. But that of the standard yard is not known; it is doubtful. I believe, if the composition of the alloy of which it is made is known, and in consequence Mr. Chaney has mentioned the determination of coefficients of expansion as one of the investigations which it is desirable that the Laboratory should undertake.

Or again take thermometry. The standard scale of temperature is that of the hydrogen thermometer; the scale in practical use in England is the mercury in flint glass scale of the Kew standard thermometers. It is obvious that it is of importance to science that the difference between the scales should be known and various attempts have been made to compare them.

But the results of no two series of observations which have been made agree satisfactorily. The variations arise probably in great measure from the fact that the English glass thermometer as ordinarily made and used is incapable of the accuracy now demanded for scientific investigation. The temporary depression of the freezing point already alluded to in discussing the Jena glass is too large; it may amount to three to four tenths of a degree when the thermometer is raised 100°. Thus the results of any given comparison depend too much on the immediate past history of the thermometer employed, and it is almost hopeless to construct a table accurate, say, to .01 which will give the difference between the Kew standard and the hydrogen scale and so enable the results of former work in which English thermometers were used to be expressed in standard degrees.

VALUES OF CORRECTIONS TO THE ENGLISH GLASS THERMOMETER SCALE TO GIVE TEMPERATURES ON THE GAS THERMOMETER SCALE FOUND BY VARIOUS OBSERVERS.

Temp.	Rowland.	Guillaume.	Wiebe.
0	0°	0°	0
10	—.03	—.009	+.03
20	—.05	—.009	+.00

30	—.06	—.002	+.02
40	—.07	+.007	+.09
50	—.07	+.016	+.14
60	—.06	+.014	
70	—.04	+.028	
80	—.02	+.026	
90	—.01	+.017	
100	0	0	

This is illustrated by giving the differences as found, (1) by Rowland, (2) by Guillaume, (3) by Wiebe, between a Kew thermometer and the air thermometer. It is clearly important to establish in England a mercury scale of temperatures which shall be comparable with the hydrogen scale, and it is desirable to determine as nearly as may be the relation between this and the existing Kew scale.

I am glad to say that in this endeavor we have secured the valuable cooperation of Mr. Powell, of the Whitefriars works, and that the first specimens of glass he has submitted to us bid fair to compare well with the 16‴. Another branch of thermometry at which there is much to do is the measurement of high temperature. Professor Callendar has explained here the principles of the resistance thermometer, due first to Sir W. Siemens. Sir W. C. Roberts-Austen has shown how the thermopile of Le Chatellier may be used for the measurement of high temperatures. There is a great work left for the man who can introduce these or similar instruments to the manufactory and the forge, or who can improve them in such a manner as to render their uses more simple and more sure. Besides, at temperatures much over 1000° C. the glaze on the porcelain tube of the pyrometer gives way, the furnace gases get in to the wire and are absorbed and the indications become untrustworthy. We hope it may be possible to utilize the silica tubes shown here by Mr. Shenstone a short time since in a manner which will help us to overcome some of these difficulties. Here is another subject of investigation for which there is ample scope.

So far we have discussed new work, but there is much to be done in extending a class of work which has gone on quietly and without much show for many years at the Kew Observatory.

Thermometers and barometers, wind gauges and other meteorological apparatus, watches and chronometers and many other instruments are tested there in great numbers and the value of the work is undoubted. The competition among the best makers for the first place, the best watch of the year, is most striking and affords ample testimony to the importance of the work. Work of this class we propose to extend.

Thus there is no place where pressure gauges or steam indicators can be tested. It is intended to take up this work, and for this purpose a mercury pressure column is being erected. Bushy House from basement to eaves is about 55 feet in height. We hope to have a column of about 50 feet in height, giving a pressure of about 20 atmospheres; it

is too little, but it is all we can do with our present building. The necessary pumps are being fitted to give the pressure and we shall have a lift set up along the column so that the observer can easily read the height of the mercury.

This column will serve to graduate our standard gauges up to 20 atmospheres, above that we may for the present have recourse to some multiplying device; a very beautiful one is used at the Reichsanstalt and by Messrs. Schaffer and Budenberg, but we are told we must improve on this.

Again, there are the ordinary gauges in use in nearly every engineering shop. These in the first instance have probably come from Whitworth's or nowadays, I fear, from Messrs. Pratt & Whitney or Brown & Sharp, of America; they were probably very accurate when new but they wear, and it is only in comparatively few large shops that means exist for measuring the error and for determining whether the gauge ought to be rejected or not.

Hence arise difficulties of all kinds. Standardization of work is impossible. The new screw sent out to South Africa to replace one damaged in the war will not fit, and the gun is useless. A long range of steam piping is wanted; the best angle pieces and unions are made by a firm whose screwing tackle differs slightly from that of the factory where the pipes were ordered. Delays and difficulties of all kinds occur which ready means for standardization would have avoided. Here is scope for work if only manufacturers will utilize the opportunities we hope to give them.

In another direction a wide field is offered in the calibration and standardization of glass measuring vessels of all kinds—flasks, burettes, pipettes, etc.—used by chemists and others. At the request of the Board of Agriculture we have already arranged for the standardization of the glass vessels used in the Babcock method of measuring the butter fat in milk and in a few months many of these have passed through our hands. We are now being asked to arrange for testing the apparatus for the Gerber & Leffman-Beam methods, and this we have promised to do when we are settled at Bushy. Telescopes, opera glasses, sextants and other optical appliances are already tested at Kew, but this work can and will be extended. Photographic lenses are now examined by eye: a photographic test will be added. And I trust the whole may be made more useful to photographers.

I look to the cooperation of the Optical Society to advise how we may be of service to them in testing spectacles, microscope lenses and the like.

The magnetic testing of specimens of iron and steel again offers a fertile field for enquiry.

If more subjects are needed it is sufficient to turn over the pages

of the evidence given before Lord Rayleigh's commission or to look to the reports which have been prepared by various bodies of experts for the Executive Committee.

In electrical matters there are questions relating to the fundamental units on which in Mr. Trotter's opinion we may help the officials of the Board of Trade—standards of capacity are wanted; those belonging to the British Association will be deposited at the Laboratory; standards of electromagnetic induction are desirable; questions continually arise with regard to new forms of cells other than the standard Clark cell, and in a host of other ways work could be found. Tests on insulation resistance were mentioned by Professor Ayrton who gave the result of his own experience. He had asked for wire having a certain standard of insulation resistance. One specimen was eight times as good as the specification; another had only one one-hundred-thousandth of the required insulation; a third had about one three-hundredth.

Mr. Appleyard again gave some interesting examples, the examination of alloys for use for resistance measurements and other purposes, the testing of various insulating materials and the like.

I have gone almost too much into detail. It has been my wish to state in general terms the aims of the laboratory, to make the advance of physical science more readily available for the needs of the nation and then to illustrate the way in which it is intended to attain those aims. I trust I may have shown that the National Physical Laboratory is an institution which may deservedly claim the cordial support of all who are interested in real progress.

CEMENT FOR A MODERN STREET.

BY DR. S. F. PECKHAM.

A MODERN street consists of a concrete foundation which extends from curb to curb, upon which is laid a wearing surface of asphalt, brick or other material.

The use of these concretes has an instructive history, which might be profitably preceded by a discussion of the uses of mortars and cements in antiquity, did space permit. So far as I have been able to learn, all the different varieties of cementing materials, including ordinary lime mortars, have been experimented with for the construction of concrete foundations. It is therefore proper that these different materials should be briefly described.

Mortar, in the ordinary sense of the term, designates a mixture of lime and sand. The lime is prepared by heating limestone in kilns, until the carbonic acid of the limestone is expelled and oxide of calcium remains, which readily absorbs water and slacks, as it is termed, and in time reabsorbs the carbonic acid that was driven off. The lime is mixed with the water when it is slacked and the carbonic acid is absorbed from the atmosphere. When mortar is made, the lime is first made into a thin paste with water, and sand is added until the mass ceases to be sticky. Such mortar acquires strength slowly. The excess of water first dries out and then the lime by slow absorption of carbonic acid forms thin particles of limestone between the grains of sand, until the mortar becomes a coherent mass. That this process goes on very slowly is shown by the fact that the mortar between the bricks of chimneys centuries old is found to contain a considerable percentage of unchanged lime. This mortar, when first laid, will not bear wetting, and will set only in dry air.

The Romans had learned before the Christian Era that the addition to lime mortar of volcanic ash or pozzuolana would make the mortar set under water and with additional strength. The so-called Roman cement was noted in antiquity for its superior strength when compared with ordinary lime mortar. Where they could not obtain the pozzuolana they used pulverized brick and pottery.

During the middle ages, for more than a thousand years, the art of making hydraulic cement was lost, and, with every other art, the art of making good mortar declined until the beginning of the eighteenth century, when attempts were made to revive the art of making Roman cement, but with only slight success.

In the year 1756, the celebrated engineer, John Smeaton, was wrestling with the problem of constructing the Eddystone Lighthouse. While experimenting with different varieties of mortar, he discovered that certain limestones produced an hydraulic lime. He found that a mortar made of pure lime and pozzuolana or powdered bricks gave only unsatisfactory results, but when an impure lime from the 'Alberthaw' was used the hydraulic properties were more fully developed. Continuing his experiments, he at length announced that only limestones containing clay produced a lime of satisfactory hydraulic properties.

Speaking of this discovery, Smeaton says in his 'Narrative of the Eddystone Lighthouse':

> It remains a curious question, which I must leave for learned naturalists and chemists, why an intermediate mixture of clay in the composition of limestone of any kind, either hard or soft, should render it capable of setting in water in a manner no pure lime I have yet seen, from any kind of stone whatever, is capable of doing.
>
> It is easy to add clay in any proportion to pure lime, but it produces no such effect; it is easy to add brick dust, either finely or coarsely powdered, to such lime in any proportions also; but this seems unattended with any other effect than what arises from other bodies becoming porous and spongy and therefore absorbent of water as already hinted and excepting what may reasonably be attributed to the irony particles that red brick dust may contain.
>
> In short, I have as yet found no treatment of pure calcareous lime that renders it more fit to set in water than it is by nature, except what is to be derived from the admixture of trass, pozzuolana and some ferruginous substance of similar nature.

These investigations and the conclusions that he drew from them led Smeaton to use in the construction of the Eddystone Lighthouse a mortar or cement composed of hydraulic lime from the Alberthaw and Italian pozzuolana. A step or two farther in his investigations, which he did not take and which were not taken until the middle of the last century, would have led to the Portland Cement of the present time.

In 1796, a Mr. Parker, of London, patented a process for what he called 'Roman Cement.' He used for this purpose certain nodules of limestone containing clay that were found along the coasts of the Isle of Sheppy and certain parts of Kent and Essex. These nodules were first calcined and then reduced to fine powder in mills. The result was a cement of a better quality than Smeaton's. In 1818, one Canvass White discovered and patented in the United States a process for making cement from a similar rock, found at Fayetteville, in central New York. Large quantities were manufactured and used in the construction of locks on the Erie Canal, which was then being built. The State of New York purchased the patent and made it public property. This laid the foundation of a great industry, which is known generally

as the 'Natural Cement Industry,' but locally in the neighborhood of New York City as the Rosendale Cement Industry.

Continuing these experiments it was found that the rocks found in a few localities produced cements of a quality superior to those in general use. This was particularly true of a stone found in the Island of Portland. At length artificial mixtures of limestone and clay were made and burned under such conditions that the resulting cement very closely resembled the natural cement made from the Portland rock. These results led to the adoption of the name of Portland for all cements of this class, whether made in England, where the name originated, or elsewhere. The first attempts to prepare a cement by artificial mixtures, in imitation of the natural Portland rock, were made in France about 1802.

Portland cements, as at present manufactured, were first made in England by a process that was patented in 1824, although there had been several patents for 'Portland Cements' previously issued. In the patent specifications of 1824 occurs the following description of the process used:

> I take a specific quantity of limestone and calcine it. I then take a specific quantity of clay and mix it with water to a state approaching impalpability. After this proceeding I put the above mixture into a slip-pan for evaporation till the water is entirely evaporated. Then I break the said mixture into suitable lumps and calcine them in a furnace similar to a lime-kiln until the carbonic acid is entirely expelled. The mixture, so calcined, is to be ground to a fine powder, and it is then in a fit state for cementing. The powder is to be mixed with a sufficient quantity of water to bring it into the consistency of mortar, and this applied to the purposes wanted.

It will thus be seen that at the middle of the last century there were in use: Common lime mortar, consisting of slacked lime and sand; made all over the world and used for common masonry and plastering.

Also Roman cement, made by mixing common lime and some dry aluminous material, like pulverized tufa, brick or slag. This was stronger than common mortar and slightly hydraulic.

Also, natural cement, called Rosendale cement in the United States, made by burning and grinding a natural limestone containing clay. These natural cements are of very varying quality and are hydraulic, *i. e.*, will set or harden under water.

Also, Portland cements, called also Artificial cements, made by grinding limestone or marl, both of which are nearly pure carbonate of lime, and mixing it in proper proportions with ground clay, which is a silicate of alumina containing a variable proportion of the oxides of iron. This mixture is calcined at a temperature that will produce semi-fusion and the resulting clinker is ground to a fine powder. The powder is 'aged' in order to partially slack the lime. The powder is mixed with

sand and water to the consistency of mortar and used. Like natural cement, Portland cements are hydraulic, and they make the strongest mortars known.

A modern street consists of a foundation of broken stone that is formed into a concrete or solid mass of masonry by admixture with mortar. The character and quality of this mortar are a matter of the greatest importance. All of the four kinds of mortar mentioned above have been used for this purpose.

An experiment was made in London by laying in Holborn, opposite Gray's Inn, nine inches of lime mortar concrete with a floating on top of ¾ inches of lime mortar. Upon this foundation was laid a surface of Val de Travers asphalte. When the concrete was ready to receive the

FIG. 1. COAL DUMPS AND INCLINES TO KILNS.

asphalte, a fire broke out in Holborn; the place was flooded with water, the engines drove over the concrete and the population of Gray's Inn trampled it down. It was subsequently made good and the asphalte spread. For five or six years the road was kept up at considerable expense and then relaid. On removing the asphalte, it was found that the lime concrete had never set, that the mortar floating had never adhered to the concrete, but was mostly in powder, produced either by the action of the rammers or by the traffic afterwards.

Roman cement was tried in Paris and condemned for street foundations. There remains for use for this purpose natural cement

and Portland cement. The details of the process of manufacture will now be given.

In the United States the manufacture of natural cements is chiefly carried on in the Lehigh Valley, near Louisville, Ky., at Akron, Ohio, at Milwaukee, Wis., and at Glens Falls and other points in the State of New York. While the rocks occurring at these different points are not identical, either in geological age or in chemical composition, they are in many respects similar. In geologic age they are of carboniferous age or older and in chemical composition they consist of limestones in which clay occurs, either uniformly disseminated throughout the rock, forming a very intimate admixture, or else interstratified with the layers of limestone, so that when the rock is broken up and burned, the resulting mixture of the constituents of the rock is very intimate. Yet intimate as the mixture is, both before and after burning and grinding, in all the ledges the rock has to be sorted and mixed in the same quarry with the greatest care, in order to insure a uniform product from the same works. From the different localities the output is sufficiently different to give the Louisville, Milwaukee and other brands distinctive, though unimportant, characteristics.

At all the natural cement works substantially the same method of manufacture is followed, although the details are modified to suit different localities.

One of the most extensive natural cement plants in the country is that of the Milwaukee Cement Co., at Milwaukee, Wis., the officers of which have kindly furnished the accompanying illustrations. Fig. 1 shows the tramway approaches to the kilns, which are arranged in a double set of ten each. The rock is quarried in the immediate neighborhood and is run in tram-cars, which are seen in the middle foreground, up the inclines to the top of the kilns into which the rock is thrown. The trestle on the right is the dump for coal, which is also loaded into tram cars, one of which is seen at the chute, and run up the incline to the kilns. The rock and fuel are thus conveniently supplied to the kilns at the top, while the burned cement is removed from the kilns at the bottom. Fig. 2 shows one of the kilns on the left; the grinding and shipping house in the center, with the inclines up which the burned cement is hauled and the railroad tracks over which the cement is shipped in all directions from Milwaukee. Fig. 3 represents the grate at the bottom of the kiln, from which the burned cement is removed, while fresh rock and fuel are supplied at the top, thus making the action of the kilns continuous.

Two obstacles make it impossible to prepare a theoretically perfect cement from the natural rock. The first is a lack of uniformity in the rock itself as it occurs in the quarry. This difficulty is obviated as nearly as is possible by careful sorting, by which the least desirable rock

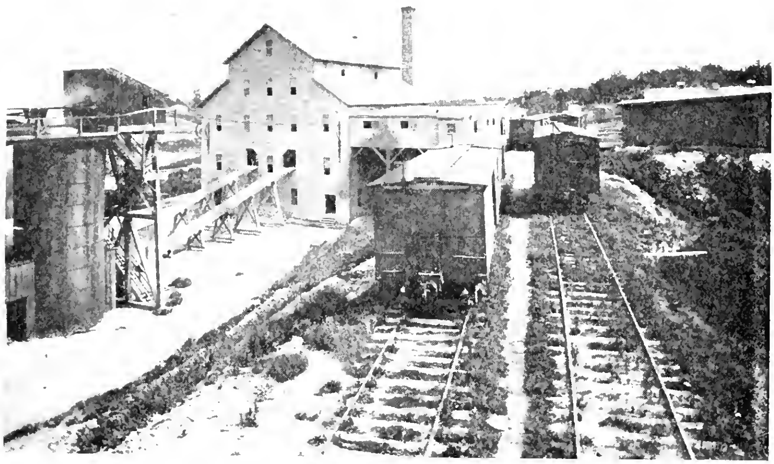


FIG. 2. INCLINES ENTERING GRINDING HOUSE AND TRACKS CONNECTING WITH ALL RAILROADS ENTERING MILWAUKEE.

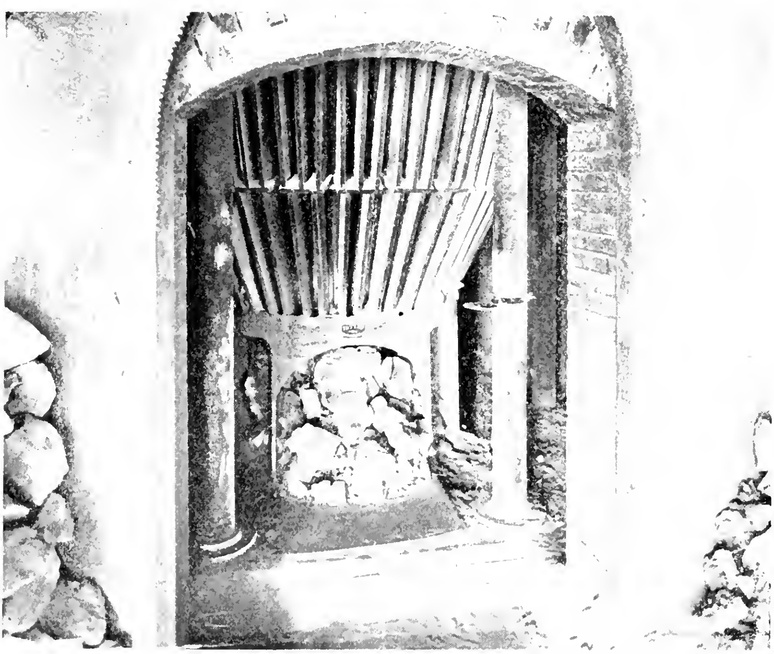


FIG. 3. BOTTOM OF KILN, CAMPBELL PATENT, SHOWING CALCINED MATERIAL.

is rejected and the varied masses selected are carefully mixed so as to ensure a uniform grade. The second is the difficulty of burning the rock in kilns and in large masses so uniformly as to ensure complete burning and no considerable amount of overburning. If natural cement rock is overburned or fused, it becomes a slag, and loses its hydraulic properties. It is not surprising, therefore, that a considerable lack of uniformity exists in the quality of the natural cement found upon the market. The best of them contain a considerable amount of impurity, or material that is not cement, that exists in the rock before it is burned, and also a considerable amount of unburned rock, which together serve to dilute the cement proper, as if a certain amount of sand had already been added to the cement before it is used. These impurities that are inherent in the nature of the materials from which the natural cement is made and also in the process of manufacture that is of necessity followed, result in a cement that can be made and sold at a less price than Portland cement and that is inferior to it for many purposes, while, on the other hand, for a great many purposes natural cements have been found to answer every requirement and are made and used in enormous quantities.

For Portland cements, either a very pure natural limestone or marl is selected and brought into a very finely pulverized condition. Limestones are selected as free as possible from every impurity except clay. Magnesia is never absent, and at best is an inert impurity, but the amount present should not exceed five per cent. Marl is frequently used and is generally purer than limestone. In England chalk is generally used. In Germany chalk and a limestone, locally known as 'mergel,' which is soft and contains clay, are employed.

The following table, No. I., taken from 'Cement Industry,' page 12, gives the composition of the carbonate of lime in use in some of the leading Portland cement manufactories in the United States:

TABLE I.

Limestones and Marls.	Chalk, England, (Reed).	Cement Rock, La Salle, Ills.	Cement Rock, Phillipsburg, N. J.	Cement Rock, Siegfried, Penna.	Marl, Sandusky, Ohio.	Marl, Syracuse, Ind.
Calcium carbonate...	98.57	88.16	70.10	68.91	91.77	88.49
Magnesium "	0.38	1.78	3.96	4.28	0.53	2.71
Calcium sulphate......					3.19	1.58
Silica	0.64	8.20	15.05	17.32	0.22	1.78
Alumina..................	0.16	1.00	9.02	7.07	1.22	0.91
Iron oxide...............	0.08	0.30	1.27	2.04	0.40	0.30

The clay should be highly siliceous, but should be free from grains of sand. Clays containing carbonate of lime or marl are softer and more easily mixed with the other materials. Clays containing 70%, or more, of silica stand firing without fusing, produce a clinker that

is easy to grind and yield a cement that sets slowly and gains strength over a long period. On the contrary, highly aluminous clays give a fusible clinker and quick-setting cement. A high authority states that the percentage of silica in the clay should be three times the percentages of the alumina and iron taken together. The less iron the clay and limestone contains the lighter colored will be the cement.

The following table, No. II., also taken from 'Cement Industry,' page 13, gives the composition of the clays in use in several Portland cement manufactories:

TABLE II.

Clays.	Medway, England.	Harper, Ohio.	Sandusky, Ohio.	La Salle, Ills.
Silica	70.56	51.50	65.41	54.30
Alumina	14.52	13.23	16.54	19.33
Iron oxide	3.06	3.30	6.06	5.57
Lime	4.43	11.52	2.22	3.29
Magnesia		3.45	1.88	2.57
Carbonic acid	3.48	12.85		
Alkalies	3.95			

A large part of the Portland cement manufactured in the United States is made from natural cement rock, that is, from a rock that contains both the carbonate of lime and clay, very intimately mixed in a natural rock. The best cements, however, are made from an artificial mixture of either limestone or marl and clay. The proportions are determined after very careful chemical analysis in such manner that the several ingredients that form cement shall not only be free from harmful substances, but shall combine to produce theoretical chemical compounds in certain quantitative relations.

Although much has been written for many years concerning the chemistry of hydraulic cements, it is only within about 25 years that researches have been conducted in such a manner that by constructing the compounds possessing hydraulic properties from pure elementary materials, much light has been thrown upon the problem. The French chemist Vicat suggested an 'hydraulic index' to designate the hydraulic properties of different cements, which is a figure representing the number of parts of silica and alumina combined with 100 parts of lime and magnesia.

In 1872 Erdmenger showed that in commercial Portland cements the ratio of lime to the acid constituents, silica, alumina and iron oxide taken together, averaged 1.9. At about the same date, Michaelis determined the ratio, as between 1.8 and 2.2, and called it the 'hydraulic modulus.' These ratios no longer represent the composition of Portland cements as with improved methods of manufacture the proportion of lime has steadily increased, until the 'hydraulic modulus' is no longer applicable to the varying conditions and materials under which the cements are now manufactured.

Since 1890 great progress has been made in the United States in the application of theoretical and scientific principles to the technology of Portland cements, and the result has been an enormous expansion of the business with an improved quality of the product.

The original method pursued in England, and largely adopted elsewhere, was to grind the materials very wet, floating off the fine particles to a large tank where they were allowed to settle. The settling and drying required a great deal of time. This method was followed by a dry process in which the materials were ground together dry and then moistened sufficiently to be molded into briquettes. The briquettes were then dried and stacked in a kiln and burned. The introduction of rotary kilns rendered the molding and drying unnecessary as either dry or wet materials, as a dry powder or wet mud are fed directly to the kilns. The composition of the materials, whether it

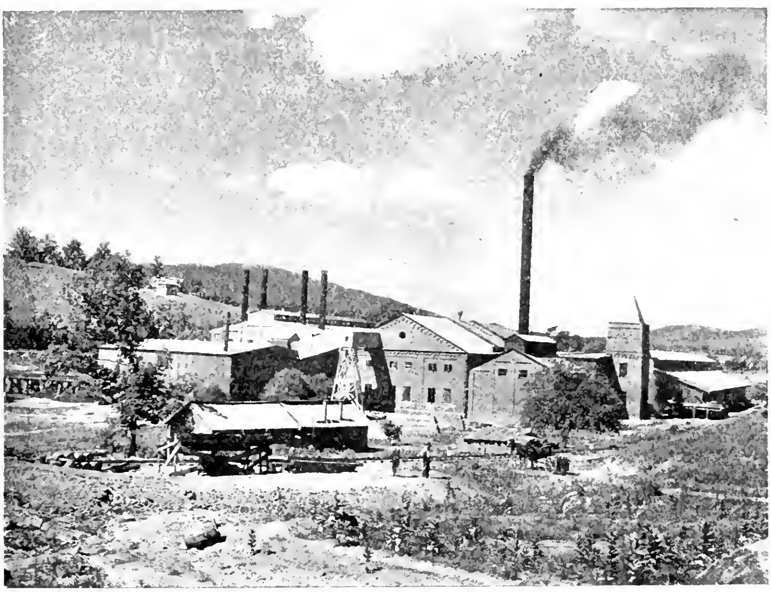


FIG. 4. GENERAL VIEW OF WORKS OF VIRGINIA PORTLAND CEMENT COMPANY, CRAIGSVILLE AUGUSTA CO., VA.

be cement rock or mixed materials, must be maintained by constant chemical analysis, as the percentage of carbonate of lime should not vary by more than ½ per cent. from that found correct for the other materials used.

From the foregoing statements it will be observed that two quite different methods of manufacture are followed. In the first the cement 'mix' is molded into briquettes, which are dried, stacked in a kiln and burned. For the burning by this method three different forms of kiln

are used: 1. The intermittent dome kilns that resemble in their operation common lime kilns. 2. Continuous kilns, of the Ditzsch or Schœfer patterns. 3. The Hoffman ring-kiln. These kilns are economical in fuel, but expensive in time and labor. The dome-kiln was the first used, but has now disappeared from the United States, and survives in Europe only in a few localities. The continuous kilns require highly skilled labor, and are used only to a limited extent either in the United States or Europe. The Hoffman ring-kiln is widely used in Europe, but has found few patrons in the United States.

The second method of manufacture of Portland cement is by the use of the rotary furnace, into which the mix is fed as a dry powder or as a wet mud. Although the rotary cement furnace was originally patented in England, by Frederic Ransome, in 1885, it has been improved in the United States to such an extent that it has become prac-

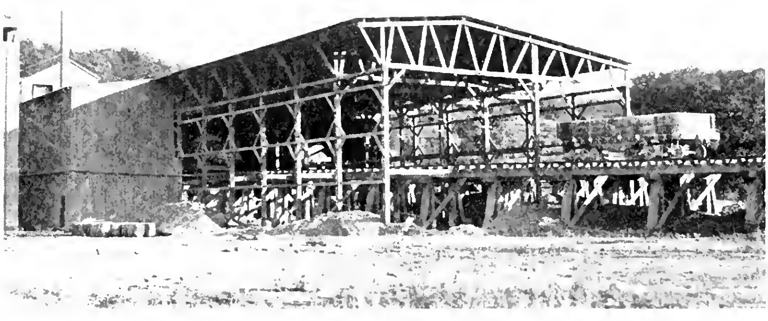


FIG. 5. STONE HOUSE WHERE MATERIALS ARE SORTED.

tically an American invention. Ransome's patent required the use of gas for fuel and the first rotary kilns installed in the United States required gas, but gas was soon replaced by crude petroleum. This fuel took the place of gas entirely, and was exclusively used until it was replaced by pulverized coal, blown into the kilns and burned in a jet like gas or sprayed petroleum. The current or blast of air which carries the powdered coal into the kiln furnishes the oxygen for its complete combustion. This is a convenient method for burning the cheapest fuel on the market, and while it is not economical of fuel it

is very economical of labor and is very uniform in its action, which is an extremely desirable condition in the cement industry.

I am indebted to the obliging courtesy of the officers of the Virginia Portland Cement Co., of Craigsville, Augusta Co., Va., for the accompanying illustrations of a Portland Cement Plant.

Fig. 4 is a general view of the works, which it will be seen at once are very unlike the natural cement works, at Milwaukee. All the operations of a Portland cement works are under cover. Fig. 5 represents

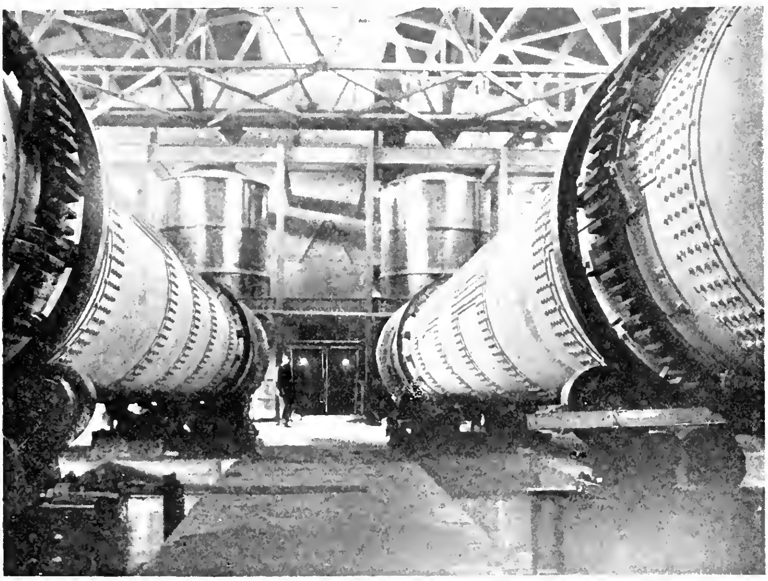


FIG. 6. ROTARY KILNS.

the stone house where the materials are received and sorted, preparatory to being finely ground. A great variety of mills are used for grinding both the crude materials and the cement clinker. So far as the making of the cement is concerned, it does not matter in what kind of a mill the ingredients may be ground, provided they be ground fine and thoroughly mixed in the right proportions. If the mixture is burned dry, the mixing is accomplished by the use of screens and sieves; if it is burned wet, the grinding is done in a wet mill, the paste being floated off and allowed to settle in large tanks. The dry materials are blown into the kiln. The wet mud is allowed to drip into the upper end of the kiln as it is forced in by a pump.

Fig. 6 represents the rotary kiln. It consists of a slightly inclined steel cylinder, about 60 feet in length and 6 to 7 feet in diameter, lined with fire-brick, and revolving by means of powerful gears at the

rate of one revolution in from one to three minutes. Fig. 7 shows the arrangement of apparatus for injecting at the center of the kiln an air blast which carries with it the powdered coal, received from the hopper shown on the right. The rotation of the kiln keeps the 'mix' in constant motion as it passes through the kiln, when it is first dried, then deprived of its carbonic acid and then vitrified or partially fused in such manner as to insure the proper chemical reaction between the basic lime and the acid silica, alumina and iron. Only that skill that is determined by experience can direct the burning at such a temperature that the continuous operation of the kilns will result in a clinker that is neither underburned nor overburned.

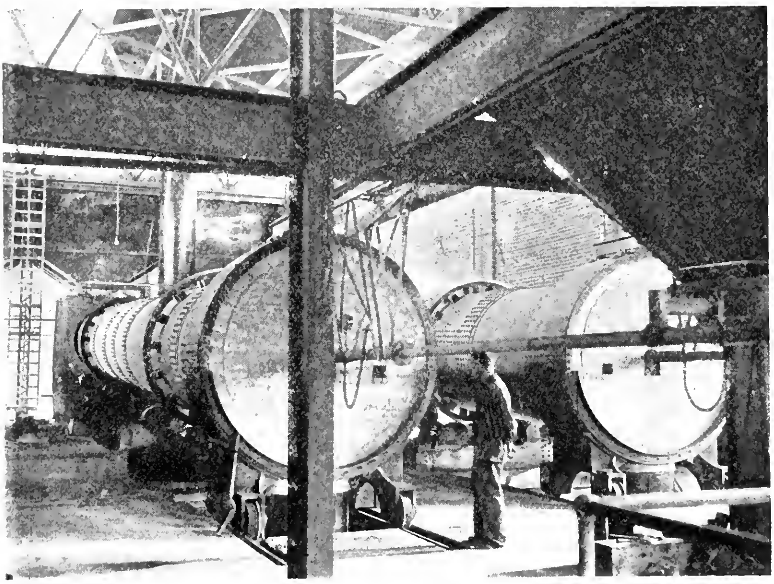


Fig. 7. Apparatus for Feeding Coal to Kilns

So far as the chemistry of cement burning is understood, it appears that at a red heat the water is expelled from the clay; the carbonic acid is then driven from the lime, and it escapes. The silica, alumina and iron of the clay then combine with the lime, first forming fusible glasses and then taking on more lime; at length the tri-calcium silicate informed with the alumina and iron as calcium alumino-ferrite.

Properly burned clinker is in hard rounded grains about the size of dried peas and of a greenish-black color. If it is underburned, it is light colored and soft. If it is overburned it becomes like slag. If it is burned too long, it falls to powder on cooling. Uneven burning is more common in vertical than in rotary kilns, hence the product of rotary kilns is more uniform, ensuring a better cement as the burning

is performed quickly and is quickly arrested when the process is completed.

Experience has proved that the burning of cement is an important factor in its manufacture as determining its qualities. A cement that is properly proportioned, thoroughly mixed and well burned and finely ground will set in about two hours after mixing with water, will harden well after setting and will continue to harden through long periods, even to several years. Ground gypsum is frequently added to cement to control the setting.

Cement should be finely ground. Ninety-two to ninety-three per cent. should pass a sieve of 100 meshes to the linear inch.

Until within the last decade, the Portland cements manufactured in the United States were generally inferior to the best English, German, Belgian and French brands. While these foreign cements have been maintained with the highest degree of excellence the American brands have been greatly improved until at the present time there are no better cements made anywhere in the world than in the United States.

THE INFLUENCE OF RAINFALL ON COMMERCE AND POLITICS.

By H. HELM CLAYTON,

BLUE HILL METEOROLOGICAL OBSERVATORY.

THE causes which control human life and human actions are complex and difficult to grasp; yet, to act reasonably and to progress, man must somehow unravel the tangle of causes and assign to each its true value.

Perhaps, in no department of life are the causes assigned for certain results more varied than in politics. Yet every man with a sense of duty toward his nation feels that he must accept some of the suggested causes as the proper ones, in order that he may form the ideals which guide his actions.

The causes popularly assigned for political and economic changes are almost universally those arising from human actions. A high tariff is assumed as sufficient cause for business prosperity by one class of thinkers, and by another class is assumed to tend toward financial distress. The threat of a silver standard in monetary affairs is considered by one party as a sufficient cause for tremendous business disturbances. With equal certainty these disturbances are considered by another party to be due to the gold standard. Even the success at the polls of a certain political party is assumed by some to be a sufficient cause for general prosperity. One well-known senator has maintained his ability to show, notwithstanding the various phases of opinion through which each of the large political parties has passed, that the success of one particular party at the polls has always been followed by prosperity in the nation, while an opposite result has followed the election of the other party.

It is not my object, nor is it possible for me here, to collect and weigh the evidence which has been given for each of these opinions. My object is to show that, besides those mentioned, there are other forces which act on man in his business and political relations, and that no satisfactory opinion can be formed as to the relative importance of the various causes until these also are considered.

As a professional investigator in science, I am frequently brought to consider the tremendous influences that natural phenomena in the earth, air and sky have on human affairs, and to wonder that these in-

fluences on man's political and business relations are not more frequently considered.

One of the fundamental needs of man, in fact a prime necessity, is a sufficient food supply. When food is abundant and hunger is satisfied there is a surplus of energy to expend on other human affairs, and this, I presume, most people will admit is the primary condition of prosperity.

The food-supply at present is obtained almost entirely from the soil, and its growth is intimately dependent on weather conditions. The relation of the food-supply to the weather has been investigated to some extent, and it is found that the factors which most powerfully influence the food-product are temperature and moisture, which latter is derived from rainfall. The annual change in temperature is comparatively regular and certain, so that the factor which, by its changes, most powerfully influences the food-product, is the rainfall.

J. T. Wills investigated the relation of the rainfall to the wheat-product per acre in south Australia for the six winter months (the growing season there), and found that for the seven best years there was a yield of 12.4 bushels of wheat with 18.5 inches of rain; for the next best years there were 10.0 bushels of wheat with 15.4 inches of rain; and for the six worst years there were 6.6 bushels of wheat with 13.5 inches of rain. The product of wheat in the first case was nearly twice as great as in the last. If such a relation holds for the United States, it is easy to understand what great effect a general drought may have on the food product. If the amount of wheat raised in the United State were reduced one half or even one third by a year of deficient rainfall, it is easy to imagine an enormous strain on the business of the country, and with a succession of such years the effect might mean disaster. Such a deficiency in the wheat supply, with wheat at 80 cents a bushel, would mean for a single year a direct loss in wealth of more than $100,000,000; it would mean that nearly all the wheat which is usually shipped abroad would be needed at home; it would mean that thousands of railroad cars and ships which ordinarily transport this grain would lie idle; that hundreds of men who usually handle this grain in transport would be out of employment; that farmers in large numbers would be unable to meet their obligations; and consequently, that banks and business of all kinds would suffer.

But the deficiency in rainfall would not affect the wheat alone; every product of the soil would likewise suffer. Rawson has worked out a simple formula in the case of Barbadoes by means of which the amount of sugar to be exported the next year can be calculated with great accuracy from the rainfall of the current year. This calculation is accurate within six per cent. in most cases. Similar calculations for Jamaica have been made by Maxwell Hall. He shows that 56 inches of

rain give 1,441 casks of sugar per acre, while 79 inches give 1,559, or about one-tenth more. This means an increase in the value of the sugar-crop alone of £100,000.

District.	Rainfall, inches.	Sheep per sq. mile.	Increased capacity for every inch of rain.
South Australia..................	8 to 10	8 to 9	1 sheep per mile.
New South Wales (1)...........	13	96	22
New South Wales (2)...........	20	640	70
Buenos Ayres......	34	2630	140

Nor is the influence of rainfall on vegetable life alone to be considered, as is evident from the following data gathered by Wills con-

TABLE COMPARING RAINFALLS, WATER-LEVELS AND COMMERCIAL CRISES.

Dates.	Departure from Normal. Rainfall in the Ohio Valley (inches).	Rainfall in the Miss. Valley (inches).	Level of Lake Mich. (feet).	Commercial Crises.	Dates.	Departure from Normal. Rainfall in the Ohio Valley (inches).	Rainfall in the Miss. Valley (inches).	Level of Lake Mich. (feet).	Commercial Crises.
1830	+2.0	......	......		1864	—0.3	—2.5	— .08	
1831	+5.1	......	......		1865	+3.0	—1.4	— .32	
1832	+1.9	. ....	......		1866	+4.0	—0.7	— .65	
1833	—1.9	......	......		1867	+1.6	—0.6	— .21	
1834	—6.1	......	......		1868	+1.1	+0.9	— .70	
1835	—6.8	......	......		1869	—1.1	+0.7	— .58	
1836	—4.5	......	......		1870	—4.7	—2.1	+ .33	
1837	—0.4	.....	. ....	Panic	1871	—7.2	—3.2	+ .26	
1838	—3.3	......	......		1872	—6.0	—2.7	—1.02	
1839	—4.5	......	......		1873	—2 7	—3.2	— .37	Panic
1840	—2.1	......	.....		1874	—0.5	—2.6	+ .12	
1841	+0.8	......	....		1875	+0.5	+1.5	— .13	
1842	+2.2	......	......		1876	—0.3	+5.5	+1.00	
1843	+2.1	......	......		1877	—2.8	+5.2	+ .77	
1844	+0.9	......	......		1878	—3.2	+2 1	+ .46	
1845	+1.9	......	......		1879	—0.3	+1.4	— .46	
1846	+6.0	......	......		1880	+3.4	+4.0	— .32	
1847	+8.3	......	......		1881	+6.4	+6.1	+ .20	
1848	+7.6	+ 6.8	......		1882	+8.0	+5.4	+ .57	
1849	+6.6	+15.6	......		1883	+6.0	+3.9	+ .72	
1850	+4.7	+22.8	......		1884	+1.0	+2.7	+ .82	
1851	+1.3	+26.4	......		1885	—2.4	+0.4	+1.07	
1852	—0.8	+21.5	... ..		1886	—2.8	—1.8	+1.31	
1853	0.0	+ 9.0	.....		1887	—1.5	—3.4	+ .67	
1854	—0.4	— 1.0	......		1888	+0.4	—3.1	+ .06	
1855	—1.0	— 2.2	......		1889	+2.9	—3.0	— .49	
1856	—2.4	+ 2.1	......		1890	+3 9	—2.5	— .40	
1857	+0.5	+ 5.2	......	Panic	1891	+1.9	—1.4	—1.16	
1858	+4.9	+ 5.3	......		1892	—1.7	—1.0	—1.27	
1859	+4.2	+ 2.2	......		1893	—4.7	—2.8	— .99	Panic
1860	+0.9	— 0.1	+1.07		1894	—7.4	—5.2	— .87	
1861	—0.5	+ 2.4	+1.05		1895	—8.1	—6.0	—1.91	
1862	—1.2	+ 3.5	+1.01		1896	—6.4	—5.2	......	
1863	—2.1	0.0	+0.54		1897	......	......	......	

cerning the number of sheep which can be pastured per square mile with different rainfalls.*

Such investigations have not been made for the United States, but the data indicate clearly the enormous variations in the food-supply, both vegetable and animal, which attend variations in rainfall; and they suggest how these variations must affect the producer, the transporter, the merchant and the consumer. Hence it is easy to imagine the great influence which variations in rainfall may have on commerce and through this on politics.

The accompanying table gives the variations in the amount of rainfall in the Ohio Valley and in the Mississippi Valley which lie about the center of the food-producing area in the United States and include a large part of this area. The data are derived from tables prepared by Professor A. J. Henry, of the United States Weather Bureau, and published by the Bureau as Bulletin 'D,' entitled 'Rainfall of the United States,' Washington, 1897. The average rainfall for each district was made up from a number of stations in the district, the same stations being used so far as the records would permit throughout the period 1830 to 1896. The sharp, irregular fluctuations which characterize the rainfall were toned down by Professor Henry by taking the means of several successive years. This process is called 'smoothing' and it renders more evident the long-period oscillations. The average rainfall for each district was obtained, and the departures of the rainfall for each year from this mean are given in the accompanying table. The plus sign indicates that the rainfall for the given year was above the mean, and the minus sign that it was below. The figures give the amounts in inches and tenths of inches. The figures for the Mississippi Valley from 1848 to 1857 are derived from the observations at one station only.†

The table also gives the departures from the mean value of the level of the water in Lake Michigan. These data have been carefully collected by the engineers on the lakes and were kindly furnished by General John M. Wilson, Chief of Engineers, U. S. Army. The figures show, in feet, the departures of the annual means from the general average. The lake may be regarded as an enormous rain-gauge. When the rainfall is in excess, the water level rises above the mean; but

* These facts are largely derived from Hann's 'Climatology,' a standard work on climate. (See Ward's English Translation.)

† Professor Henry also gives the rainfall for New England. Although the oscillations run roughly parallel to those in the interior valleys the data are not reproduced here, (1) because Mr. E. B. Weston has shown that the early measurements are probably deficient on account of the methods of measuring the snowfall; (2) because New England has largely ceased to be an agricultural region.

during droughts evaporation exceeds the supply, and the level falls below the mean. Alongside of these data are indicated the dates of the severe financial panics in the United States. The dates of these panics were taken from one of the current histories of the United States.

The table shows that the observations in the Ohio Valley began during a period when the rainfall exceeded the average amount. This lasted through 1832, after which a severe drought set in, lasting until 1840. The severe financial panic of 1837 occurred in the midst of this drought and about two years after the greatest deficiency of rainfall in the Ohio Valley. The rainfall statistics for New England show that there was also a very severe and protracted drought in the eastern states at that time, culminating in 1836 to 1837, when the annual rainfall was nearly nine inches below the normal. In 1841 began a period of excess in rainfall lasting until 1853, after which a period of drought set in, culminating in 1855 in the Mississippi Valley, and in 1856 in the Ohio Valley. This was followed by the severe financial panic of 1857. This was in turn followed by another period of excess in rainfall, lasting until 1860 in the Ohio Valley, and until 1862 in the Mississippi Valley, when another period of deficient rainfall set in with the greatest deficiency in 1863 and 1864. Any commercial effect attending this drought was overshadowed by the tremendous disturbances in the life of our country attending the civil war. Another period of excessive rainfall occurred between 1866 and 1869, followed by a severe drought which reached its maximum in the Ohio Valley and Mississippi Valley in 1871, and in the Lake Region in 1872. This was followed by the severe panic of 1873. This in turn was followed by another period of excessive rainfall which began in the Mississippi Valley in 1875, in the Lake Region in 1876 and in the Ohio Valley in 1879 and lasted until between 1884 and 1887. This was accompanied and followed by a period of unusual business activity and enterprise, especially in our western states. With 1887 began a long and severe drought, lasting nearly ten years and reaching its maximum severity in 1895. During this interval the United States was well covered by observing stations and permitted Professor Henry to make an investigation of the deficiency of rainfall for the entire United States. He says, in speaking of this interval, 1887 to 1896, "It appears beyond question that there has been a very general deficiency of rain in the great majority of the years and in almost all the districts. Moreover, there does not seem to be any law of compensation by which a deficit in one district is balanced by a surplus in another. The South Atlantic and Gulf States, in particular, show a marked deficit throughout almost the entire period." This drought was relieved in some sections about 1889 to 1891, as in the Ohio Valley, by an excess of rainfall for two or three years. In the midst of this drought

occurred the severe financial panic of 1893 to 1894. This panic occurred one or two years before the greatest deficiency of rainfall and thus differed from the preceding panics which occurred one or two years after the greatest deficiency. But a very marked depression in business activity continued throughout the interval 1893 to 1897 inclusive.

It is thus evident that every severe financial panic has been closely associated with a protracted period of deficient rainfall, and there has been no period of protracted drought without a severe financial panic except a period, the effects of which were masked by the large disturbances attending our civil war. Hence, it is difficult to avoid the conviction that periods of deficient rainfall are the paramount causes of the periods of commercial distress, especially when the means by which the two are connected are so reasonable.

As another link in the chain of causation, it is interesting to trace the coincidences between the periods of deficient rainfall, deficient food supply and financial panics and the subsequent changes in political life.

Concerning the panic of 1837, I quote the following from a current history, "The panic of 1837 was a severe blow to Van Buren and his party. A slight return of the panic in 1839 completed the work; and though his party stood manfully by him and renominated him for the presidency, he was defeated by the Whigs . . . like Jackson, on a wave of enthusiasm, 'Tippecanoe and Tyler too' were triumphantly elected."*

In the presidential election following the financial panic of 1857, that of 1860, the Democratic party which had previously been in power was disorganized and broken into factions, and the new Republican party sprang triumphantly into power. However, it is probable that the great issue of slavery had a large share in these occurrences.

The first national election after the financial panic of 1873 was that of 1874, when the Republican majority of 107 in the House of Representatives was turned into a Democratic majority of 74, and two years later the Democratic party failed in obtaining the presidency only by the narrowest margin, although the country at the previous presidential election had been overwhelmingly Republican.

The political effects following the commercial crisis of 1893 to 1894 were very striking. The Democrats who were then in power, realizing that they were held responsible for the commercial distress, abandoned every important issue for which they had previously stood, and, even repudiating their former leader and his opinions, nominated a new leader, the champion of a new issue. But this in no way saved them from overwhelming defeat at the next election. The marked disturb-

* 'A History of the United States' by Allen C. Thomas, Boston, 1899.

ances in civil life following the commercial panic of 1893 was shown by the 'Coxey army of 1894' and the Chicago riots.

It is interesting to read the various causes given for financial panics and political upheavals even by historians. In 1837, the cause was said to be the State Banks. In 1857, it was the too rapid railroad expansion. In 1873, it was the reaction from the lavish expenditures attending the civil war and the contraction of the currency. In 1893, it was the low tariff and the 'free silver craze.' All of these may have been contributory causes, but if my assumption is correct that deficiency of rainfall is the paramount cause in this chain of events, then vast political and historical changes have been brought about, and the thoughts of men have been swayed by opinions which are akin to superstitions, because they attribute to human action what is due largely to natural causes beyond the control of man.

The recent period of financial distress (1893-97) in the United States was also a period of financial distress in Europe. This may have been due to the fact that Europe depends to a large extent on the United States for its food supply; or to the fact (which recent observations seem to indicate) that long periods of drought and excessive rainfall embrace a large part of the world, if not the whole world, in their operations, and are due perhaps to changes taking place in the sun.

The following extract from an American newspaper reprinted in the English periodical 'Nature,' 1895 (Vol. 53, p. 78), shows that severe droughts in other parts of the world were coincident with the one in the United States:

> The long drought, which has caused so much inconvenience and damage this fall, seems to have prevailed all round the world, if not in every part of it. Europe has experienced it almost equally with this country, and in Australia it has been more severe than here. So great was the distress in New South Wales, that the Government appointed a Sunday in September as a day of prayer for rain, and special services in accord with the proclamation were held in all the churches of every denomination in Sydney and throughout the province. The drought occurred in the antipodean spring, and greatly retarded planting operations, as well as doing great general damage. In many districts the grass was literally burned off the earth, and the mortality among stock was great. The railway trains carried supplies of water from lakes and rivers to all stricken points along the lines, selling it at the rate of 25 cents a thousand gallons. The water supply of many towns entirely failed, the inconvenience experienced was acute everywhere, and many agriculturists were ruined.

The existence of this drought is confirmed by recent meteorological reports from Australia. (See 'Science' of January 11, 1901, p. 75. A note concerning a simultaneous drought in Great Britain is found in 'Nature,' 1895, Vol. 52, p. 597.). These years were followed by rapid changes in political parties in Europe, especially in Great Britain and France.

On the other hand, the parties which are in power, when the increased rainfall and subsequent prosperity reappear, claim and get the credit for it, and are usually returned to power by large majorities. In France, the present ministry has been in power for several years; in England, the conservatives have been returned with immense majorities; in Canada, the liberals were equally successful; and in our own country, the republicans were returned on a 'tidal wave.'

To designate as a superstition the belief in the capacity of the various political parties in power to make prosperity may be extreme, but certainly careful thinkers will join in the wish that such relations to natural phenomena as are here outlined might be carefully studied by trained investigators, using well-known scientific methods. Perhaps, then a unity of belief as to the causes of commercial distress might be obtained equaling that which has prevailed since Darwin's day as to the causes of variety and changes of form in the animal kingdom.

Would that some wise benefactor would found an institution purely for research, where all such questions of man's relation to the universe could be carefully investigated by trained investigators using the well-tried and fruitful methods of science!

Such an institution should be perfectly free and independent of the control of any other institution or party and especially should it be free from Government control. No man should be appointed to it because he believes in certain current theories, as, for example, free trade, and would give free trade statistics while the free trade party was in power, only to be dismissed and replaced by a man who would give high tariff statistics while the high tariff party was in power. His loyalty should be to the truth alone, and he should be allowed perfect freedom of expression for his results and conclusions, however much they might differ from accepted beliefs.

Such an institution, with an adequate endowment, devoted without let or hindrance to the search for truth in every field of human activity, would be of inestimable value to the nation.

Our universities, performing the threefold functions of training in methods, diffusing knowledge and investigating the laws of nature, are undoubtedly an immense power for progress in the nation. But they have strangely neglected the atmosphere and its relations to man. In only one university of our nation is there a professorship of climatology, and that of so recent a date as to be almost of the present. Is it any wonder that the influence of our atmosphere on health, commerce and politics is so little known? The work in meteorology in America heretofore has been almost entirely outside of our universities; but surely this cannot last. Our universities should somehow find means to give the study and teaching of meteorology their rightful and independent places.

LUCRETIUS AND THE EVOLUTION IDEA.

By Professor WILLIAM L. POTEAT, M.A.,
WAKE FOREST COLLEGE.

Felix, qui potuit rerum cognoscere causas,
atque metus omnes et inexorabile fatum
subiecit strepitumque Acherontis avari.
—Virgil, Georg. II. 490–492.

It seem'd
A void was made in Nature; all her bonds
Crack'd; and I saw the flaring atom streams
And torrents of her myriad universe,
Ruining along the illimitable inane,
Fly on to clash together again, and make
Another and another frame of things
Forever: that was mine, my dream, I knew it.
—Tennyson, Lucretius.

Lucretius, nobler than his mood,
Who dropped his plummet down the broad,
Deep universe, and said, 'No God,'

Finding no bottom: he denied
Divinely the divine, and died
Chief poet on the Tiber-side

By grace of God: His face is stern
As one compelled, in spite of scorn,
To teach a truth he would not learn.
—Mrs. Browning, A Vision of Poets.

IN the essay on Dante, Macaulay reproached the English poets with the tendency then showing itself among them to consider the objects and phases of external nature fit material for the exercise of their art. The reproach arose in part out of the fancied antagonism between poetry and science, and it has been often echoed since that day by poets as well as critics.

The judgment is a shallow one. Poetry is, indeed, imaginative. Whatever else it may have or want, it ceases to be poetry when the glow of imagination fades out of it. Science, on the other hand, occupies itself with fact only, with things as they are observed to be, not as they are imagined to be. But imagination and observation are not at war with each other. Distinction is not opposition. And, besides, the poet's constructive imagination is helpless without the materials supplied by observation; and the scientist's observation is aimless and unfruitful without the stimulus and guidance of imagination.

But a simpler and perhaps more decisive proof of the near and hospitable relations of poetry and science is presented in the cases of their actual union in the same person. When imagination ceases to be mistress and becomes servant to observation, your poet turns scientist. When observation yields the scepter to imagination, your scientist turns poet. The names of Maxwell, Tyndall, Romanes and Huxley suggest themselves as examples of scientists of the first rank whose poetic gift is manifest in their published poems. Of the poets of the first rank who have shown the scientific turn and interest, one thinks first of Tennyson. He studied medicine until he imagined that he had all the diseases set out in the books. His interest in astronomy he maintained to the time of the 'twilight and evening star.' From his student days at Cambridge when 'the fairy tales of science' first won him, even down to the 'Locksley Hall Sixty Years After,' he meditated deeply on evolution. The scientists of his period looked upon him as their most intelligent mouthpiece in the world of letters. Goethe, it is well known, felt more satisfaction in his scientific achievements than in the poems which made him the chief figure in German literature. It was a comparatively small thing to have written 'Faust,' but to be the only person of his century who understood the science of colors—that was a thing to be proud of.

Classic, as well as modern, literature offers illustrations of the union of the poetic and the scientific interest. There are some extant lines of Virgil headed, 'Virgil abandons other studies and embraces the Epicurean Philosophy.' That this love of science—for ancient philosophy included science—was no transient passion is attested by poems on natural objects and by passages in the Georgics, the Eclogues and the Æneid. His last fatal journey to Greece and Asia was undertaken in order that he might complete the Æneid, and then devote the remainder of his life to science. But in all the history of literature, the best example of the fellowship of science and poetry is Lucretius, the poet in whom we are here particularly interested; for he was not at one time poet and at another time scientist, but rather both at once. It is Mrs. Browning's judgment that Lucretius 'died chief poet on the Tiber-side,' and a *Quarterly Reviewer* has recently declared him to be Rome's truest man of science. But such eminence in the two spheres is paralleled in the case of Goethe. What makes the work of Lucretius quite unique is the fact that his first-rate poetic capacity cooperates with his capacity for science in the same task. The poet's imagination kindles into beauty the scientist's perceptions, and the issue is a poetical treatise on physics and biology, or, if you prefer, a science poem.

It is true that a certain type of mind in the eighteenth century was drawn to Lucretius, recognizing in him a sort of fellowship of

skepticism. But his present vogue dates only from the middle of the nineteenth century, when the great questions which he treated reached again the acute stage of interest. The search into the constitution of matter and the origin and development of living beings, and the sharp antagonisms of science and theology, which have distinguished the past half century, called out of obscurity the poet-scientist who, quite alone, passed over the same path two thousand years before. On account of this kinship of task and attitude Lucretius, to the modern man of science, is better known than any other ancient poet.

Professor Jowett used to say that all that was really known of Shakespeare might be written on half a sheet of note-paper. Of Lucretius very much less is known. Indeed, with the single exception of Homer, there is no considerable writer of antiquity whose personal history is so meager and vague. Two sentences by the Christian Father Jerome and a single sentence by Donatus constitute his extant biography. The statements of Jerome are—that Lucretius was born in the year B. C. 94; that, having been made insane by a love-potion, he wrote, in the intervals of insanity, certain books which Cicero corrected; and that he died by his own hand in the forty-fourth year of his life. Donatus in his 'Life of Virgil' informs us that, on the day when Virgil assumed the toga virilis, Lucretius died. By the help of Donatus we can correct the birth-date given by Jerome, and fix it at about the beginning of B. C. 98. The story of the philtre, insanity and suicide is probably a legend with a historic germ of some unknown tragedy in his life. Upon that legend Tennyson has made his poem of 'Lucretius,' which is a marvel at once of faithful portraiture and of exquisite beauty.

If we turn through the 'De Rerum Natura' in hope of chance self-revelations of the author, we are disappointed. He is almost as impersonal as Shakespeare. He lets fall no fact of his station or fortunes in life. We do, however, discover some of his personal characteristics. Here is an austere and serious student of the problems of nature and of human life and destiny. He is, as he says himself,* not only a philosophical teacher and a poet, but also a moral reformer, and so ardent is his zeal to effect his practical aim of emancipating men from the bonds of superstition that he subordinates to it both his philosophy and his poetic passion. His praise of the tranquil, obscure life suggests that he knew and loved it. We are warranted in inferring that he was the social equal of C. Memmius to whom his poem is addressed and that accordingly he was of the governing class. But we catch hints here and there that the political history of the last years of the Republic only repelled and distressed him, and, having no leaning

* I. 931–934.

to social pleasure, he chose to lead the retired and contemplative life. The Epicurean ethics, which he accepted, produced diverse practical results according to the natures which received it. In shallower natures, like those of Catullus and Horace, it produced an easy-going life of pleasure-seeking; in deeper natures, like Lucretius, Virgil, Epictetus, the same system showed itself in a sincere and strenuous moral life closely akin to that of the Stoics. We may, therefore, accept as historically true and as being well within the suggestions of the poem, the words which Tennyson puts into the mouth of Lucretius:

> I thought I lived securely as yourselves—
> No lewdness, narrowing envy, monkey-spite,
> No madness of ambition, avarice, none:
> No larger feast than under plane or pine
> With neighbors laid along the grass to take
> Only such cups as left us friendly-warm,
> Affirming each his own philosophy—
> Nothing to mar the sober majesties
> Of settled, sweet, Epicurean life.

We discover, moreover, his absolute sincerity and devotion to truth, his large and reverential conception of the sum of things—the *majestas cognita rerum*—his high moral purpose and poetic fervor which sustain him throughout a prolonged and difficult achievement at an unusual elevation of thought and passion. As Professor Sellar remarks, he combines in himself the Greek ardor of speculation and the Roman's firm hold on reality, the theorizing passion of the dawn of science with the minute observation of its meridian.

So far as we know Lucretius left but one work, the 'De Rerum Natura,' *i. e.*, 'The Constitution of Things,' but that single work will, as Ovid prophesied, preserve the memory of his genius until the world disparts in its final catastrophe. Certainly in all the record of literary effort, the poem is unmatched in at least one respect: it is a closely reasoned system of natural philosophy in verse. Tennyson's 'Two Voices' has been mentioned as like it in the wealth of poesy enlisted to beautify abstruse argument. But the subject-matter of that striking poem is different and yields itself more kindly to poetic treatment; it seems, moreover, to be but a short 'swallow-flight of song' beside the sustained elevation and wide sweep of the ancient master. Lucretius had the example of Empedocles for the poetic form of his treatise, but that alone would not have determined his choice. Two other considerations moved him—first, his own poetic impulse, and, second, the wish to make an unfamiliar doctrine attractive; he would overlay it, as he says, with the pleasant honey of the muses.

But the purpose of the poem is not the emulation of the Sicilian poet-philosopher, nor yet the gratification of his own sense for beauty.

He imposes on himself a far graver task. After a pathetic recital of the sacrifice of Iphigenia on the altar of religion by the hand of her father, Lucretius writes the great line of the poem—

Tantum religio potuit suadere malorum—

such are the evils to which religion leads! And he soon adds, "This terror and darkness of mind must be dispelled, not by the rays of the sun and the glittering shafts of day, but by the aspect and law of nature." His lofty aim is no less than the permanent defeat of the ancient reign of superstition by setting forth the new knowledge of nature.

The poem is in six books, which aggregate nearly seven and a half thousand lines. It is not far from three-fourths the length of 'Paradise Lost.' In the first book Lucretius expounds the physics of his great master Epicurus, starting with the fundamental principle that nothing comes from nothing, and the other that all that is is either atoms or space. In the second book he derives all the properties of things from the shapes and concourse of the atoms. The remaining books apply the general principles of the first two to sensation and the doctrine of the soul's immortality, the origin and the final ruin of the mass and fabric of the world, the origin of plants and animals, the rise and development of human civilization, and lastly the explanation of certain terrifying phases of nature, as thunder, earthquake, volcanic eruptions and the plague.

If it be asked, How can this exposition of ancient physics, biology and physical geography be poetry? it must be answered that much of it is not poetry. But the same is true of 'Paradise Lost' or 'The Ring and the Book.' A poem is to be judged, not by the proportion of prosaic content which it carries, nor by successes or infelicities of detail, but by the single impression which it makes considered in its totality. Judged by this standard the poem of Lucretius is one of the world's masterpieces. It becomes all the more remarkable when we recall the limitations under which the poet worked: the language in which he wrote had hitherto been all unused to the music of verse, the exigencies of the exposition of an obscure and prosaic subject-matter dominated the treatment, and the yoke of a practical moral purpose was always on the neck of the poetic impulse.

Of course the value of Lucretius does not lie in his science, and yet our subject demands some consideration of at least one feature of his scientific system. In the first place, he has, amid many puerilities, some curious foreshadowings of modern scientific opinion. The following may be cited: the eternity of matter;[1] the conservation of matter[2] and of force[3]—Haeckel's 'law of substance'; the atomic con-

[1] I. 149, 150. [2] I. 215–266; II. 294–307. [3] II. 294–307.

stitution of matter;[1] the doctrine of films,[2] which recalls Newton's corpuscular theory and the very recent discovery of the 'Becquerel rays'; the relations of waste and repair in youth and age;[3] the inviolability of natural law.[4]

Of special interest to us is a passage in the fifth book[5] which sets forth the ideas of the struggle for existence and natural selection in terms of remarkable clearness for a pre-Darwinian writer. Lucretius even announces them in connection with the domestication of animals, which was the precise point from which Darwin started in his effort to account for 'the origin of species.'

> And many races of living things must have then died out and been unable to beget and continue their breed. For in the case of all things which you see breathing the breath of life, either craft or courage or else speed from the beginning of its existence protected and preserved each particular race. And there are many things which, recommended to us by their useful services, continue to exist consigned to our protection. In the first place, the fierce breed of lions and the savage races their courage has protected, foxes their craft and stags their proneness to flight. But light-sleeping dogs with faithful heart in breast and every kind which is born of the seed of beasts of burden and at the same time the woolly flocks and the horned herds are all consigned, Memmius, to the protection of man. For they have ever fled with eagerness from wild beasts and have ensued peace and plenty of food obtained without their own labor, as we give it in requital of their useful services. But those to whom nature has granted none of these qualities, so that they could neither live by their own means nor perform for us any useful service in return for which we should suffer their kind to feed and be safe under our protection, those, you are to know, would lie exposed as a prey and booty of others, hampered all in their own death-bringing shackles, until nature brought that kind to utter destruction.[6]

In close sequence comes the most interesting portion of the entire poem, the detailed account of the evolution of human society from the rude 'life after the roving fashion of wild beasts' up to the settled security and elegancies of the highest civilization. Noteworthy in this account is the representation of childhood as the first humanizing influence, the origin and growth of language, religious beliefs and social order, the development of industries and of art, until the poet himself appears 'to consign the deeds of men to verse.' Thus, says Lucretius, "time by degrees brings each several thing forth before men's eyes, and reason raises it up into the borders of light; for things must be brought to light one after the other and in due order in the different arts, until these have reached their highest point of development."

[1] I. 267–328; II. 80–141, 333–477, 660–699.

[2] IV. 29 f.

[3] II. 1118–1147.

[4] V. 55–58.

[5] V. 855–877.

[6] Here, as elsewhere, I have used Munro's translation.

These citations of the evolution idea in Lucretius are a sufficient refutation of the popular notion that somehow Darwin is responsible for the invention of this revolutionary conception. Indeed, the doctrine of evolution is itself one of the best illustrations of the law of evolution, for it has a continuous, progressive history of twenty-five centuries. It stretches the slow process of its rise and development from Thales' 'evolution's morning star,' more than six hundred years before Christ, down to the present hour. The hazy surmises of the early Greek speculation become precise and organic in the teaching of Aristotle, that nature proceeds by gradual transitions from the most imperfect to the most perfect, that the higher species are descended from the lower, that man is the highest point of a long and continuous ascent. The idea thus definitely enunciated by 'the master of those that know,' may be traced through Lucretius to the Christian theologians of the medieval period, and from them to the philosophers and naturalists of the seventeenth and eighteenth centuries. At the beginning of the nineteenth century we meet Lamarck, the most important figure in this history since Aristotle. His 'Zoological Philosophy' (1809) is the first elaborate exposition of the means or factors of evolution as applied to the origin of living forms. From his day the descent of the higher organisms from the lower was a standing question among naturalists until the publication of Charles Darwin's 'Origin of Species' in 1859. That splendid product of a great mind brooding for years on an enormous mass of facts, practically closed the question and won at once the almost unanimous assent of the naturalists of the world.

Our old-world poet not only takes an honorable place in the historical development of scientific opinion, but also illustrates in his own person certain modern phases of the relation between science and religion. He has been called the high-priest of atheism and the apostle of irreligion. He does deny Providence and the future life with great elaboration of argument; he does scout with vehemence the current theology and worship. And this, too, in the name of his scientific system. But was his science atheistic and irreligious? His fierce indignation—does it burn against the gods themselves, or against the popular conception of the gods? Does he despise religion itself, or the 'foul' perversion of it?

Respecting Lucretius' opposition, in the name of science, to religion, it is to be borne in mind that, speaking generally, the Romans had no genius for religion. They were called unto politics, as the Hebrews were called unto religion. The national religion derived what vitality it had from its alliance with the civic spirit, and with the decline of that spirit, religion dropped into cant with a meager and barren ritual and a train of grotesque superstitions. It was at times polluted by

shocking immoralities, and there are hints here and there of human sacrifices. The future life, even when it was allowed, was far from attractive to a noble spirit, being a sort of languid and aimless shadow of the present life. The Roman gods are vague abstractions with no appeal to the imagination or enthusiasm of their votaries, and, so far as they touch human life at all, malevolent and irresistible. This was the body of religious beliefs and practices against which Lucretius protested in the interests of humanity. In doing so, he showed his essentially religious nature. 'He denied divinely the divine.' The divine within him recognized nothing kindred in what was currently called divine, and he invoked the aid of science to dispel 'this terror and darkness of mind.'

SENSORY MECHANISM OF PLANTS.

BY D. T. MACDOUGAL,

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THE relation of the vegetal organism to its environment has demanded a much more generalized type of sensory action than that of the animal. Thus but few species of plants have developed special perceptive organs. The sensory functions are exercised by extended regions of the body, yet the delicacy of appreciation of differences in the intensities of external forces is not surpassed by that of the animal. Thus no plant has sensory organs for the reception of light-stimuli, yet, as a matter of regulation of their main function of food-building, leaves react to differences in intensity far beyond the range of the unaided human eye. Special tactile organs are differentiated in tendrils and in certain 'carnivorous' species and 'sensitive' plants,

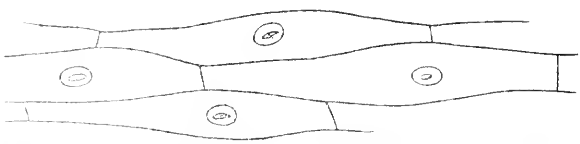

FIG. 1. SURFACE VIEW OF CELLS OF PERCEPTIVE REGION OF THE COLUMNA OF *Stylidium graminifolium*. AFTER HABERLANDT.

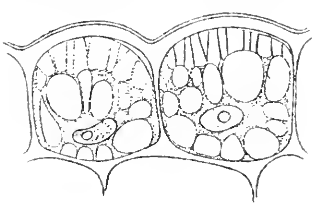

FIG. 2. LONGITUDINAL SECTION THROUGH A SINGLE PAPILLA OF AN EPIDERMAL CELL OF THE COLUMNA OF *Stylidium graminifolium*, WHICH IS SENSITIVE TO CONTACT.

FIG. 3. EPIDERMAL CELL OF THE PERCEPTIVE LAYER OF TENDRIL OF *Entada scandens*.

in which members are adapted to a narrow and unusual non-typical purpose. Here also great delicacy and accuracy is obtained, and the contact or weight of a body inappreciable to the sense of touch of any known higher animal may act as a stimulus. This refinement of reaction in undifferentiated tissues is quite remarkable. As a further instance it may be cited that leaves of certain seedlings are capable of appreciating an intensity of light equal to .00033 of a standard candle.

Very naturally the first studies made in this subject attempted to discover an arrangement in plants comparable to a simplified neuromuscular system of the animal. Expectations of this character were of course bound to meet with signal disappointment; a fact that should have been apparent if the history and widely different purpose of the animal and vegetal organism had been taken into consideration. Parallelisms between the reactions of plants and animals even to the same class of stimulus are to be accepted with great caution. Thus it has recently become apparent that the heliotropism of animals as investigated by Loeb is widely different from the heliotropism, or phototropism, of plants both as to the features of light acting as stimuli in the separate cases, and the general nature of the consequent reactions.

Recent papers by Nemec on the transmission of impulses in plants, and the discussions of geotropism and the organs of equilibrium of plants by Noll, Czapek and Haberlandt have awakened much interest in the mechanism of irrito-motility of plants.

Not fully appreciating the significance of the diffused and generalized forms of perception organs, much effort has been directed toward fixing on specialized protoplastic tracts, with functions analogous to nerves. The quest has not yet met with decided success in any single instance. We have, however, arrived at the general conclusion that the ectoplasmic layers of the protoplasts of peripheral cells function as sensory organs, and that impulses are transmitted between the motor and sensory zones by these layers and their interprotoplastic threads. As to the nature of the impulse, one can only hazard a meaningless guess that it may consist in a chain of chemical, catalytic or osmotic disturbances.

Two noteworthy attempts have been made to ascribe the function of transmission of impulses to specially differentiated structures. The first was by Haberlandt who dealt with the transmission of impulses in

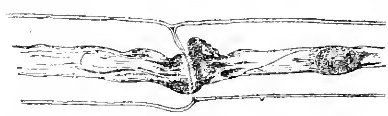

FIG. 4. ELONGATED ELEMENTS OF *Mimosa* SUPPOSED BY HABERLANDT TO TRANSMIT HYDROSTATIC IMPULSES.

Mimosa, the common 'sensitive plant' of the tropics, cultivated in conservatories. An impulse set up at the tip of a pinnule of one of these plants is conducted through petioles, stems and branches to a distance of a meter at a rate varying from 6 to 21 mm. per second. A study of the structure of the plant reveals the presence of a connected series of long tube-like cells in the fibro-vascular bundles, usually turgid, and containing relatively small protoplasts. It is argued that impulses take the form of hydrostatic disturbances communicated through the system

of tubes. This conclusion, however, disregards many well-known adverse facts. Thus it is possible to secure the conduction of an impulse through a section of stem, one or even two centimeters in length, which has been killed by a steam jacket and allowed to desiccate. Then again, when excised stems have been placed in connection with the most powerful force pumps, or the action of the strongest osmotic solutions, and artificial disturbances set up, no reactions were induced in the pinnules, although great hydrostatic movements must have been initiated. The above mentioned hypothesis must be declared 'not proven,' although it is a puzzling matter to attempt any suggestion of a method by which transmission could be accomplished through 2 cm. of dead tissues, and a meter of living tissue.

FIG. 5. FIBRILLAR STRUCTURES IN CELLS OF PLEROME OF ROOT OF ONION SUPPOSED BY NEMEC TO TRANSMIT IMPULSES.

Nemec finds a somewhat regular coincidence of fibrillar structures in the apical portions of roots, with the pathway which impulses should travel in passing from the perceptive region to the motor zones. The occurrence of these structures has been well known for some time, and the theory of their function as special transmitting organshas something in its favor, especially as these fibrillae have continuous intercellular communications. No facts are at hand to suggest the presence of these fibrillar organs in other members of the body.

The decentralized organization of the plant, the intimate and delicate morphogenic and physiologic correlations existing among all its members and its reflective system of irritability, make unnecessary, and preclude, the differentiation of transmitting tracts, except in certain narrowly specialized organs adapted to other than their typical vegetative purposes. The most recent hypothesis as to the geotropic action of the

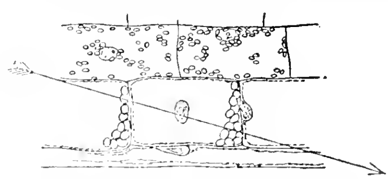

FIG. 6. STATOLITHIC ACTION OF CELLS OF STELAR SHEATH CONTAINING STARCH, BY THE AID OF WHICH EQUILIBRIUM IS SUPPOSED TO BE MAINTAINED.

plant is in accordance with these ideas. By this theory the maintenance of equilibrium is made possible by the appreciation of gravity as the result of the position of granules in sheath cells in every part of the body, these cells acting as statoliths and sending impulses to the motor zones of the organs in which they are found.

ON THE RECEPTION OF THE 'ORIGIN OF SPECIES.'*

BY PROFESSOR HUXLEY.

TO the present generation, that is to say, the people a few years on the hither and thither side of thirty, the name of Charles Darwin stands alongside of those of Isaac Newton and Michael Faraday; and, like them, calls up the grand ideal of a searcher after truth and interpreter of Nature. They think of him who bore it as a rare combination of genius, industry, and unswerving veracity, who earned his place among the most famous men of the age by sheer native power, in the teeth of a gale of popular prejudice, and uncheered by a sign of favour or appreciation from the official fountains of honour; as one who in spite of an acute sensitiveness to praise and blame, and notwithstanding provocations which might have excused any outbreak, kept himself clear of all envy, hatred, and malice, nor dealt otherwise than fairly and justly with the unfairness and injustice which was showered upon him; while, to the end of his days, he was ready to listen with patience and respect to the most insignificant of reasonable objectors.

And with respect to that theory of the origin of the forms of life peopling our globe, with which Darwin's name is bound up as closely as that of Newton with the theory of gravitation, nothing seems to be further from the mind of the present generation than any attempt to

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* In the last issue of THE POPULAR SCIENCE MONTHLY the original announcement by Darwin and Wallace of the theory of organic evolution by natural selection was reprinted from the 'Journal' of the Linnean Society for 1858. The 'Origin of Species' was published on November 24, 1859; its reception by scientific men, by churchmen and by the general public forms one of the most interesting chapters in the history of science. We reproduce part of the account of the matter contributed by Huxley to 'The Life and Letters of Darwin' (1887), and extracts from the reviews published in 1860 in the 'Edinburgh Review,' attributed to Richard Owen, and in 'The American Journal of Science' by Louis Agassiz and Asa Gray. Regarding the Edinburgh reviewer Darwin wrote to Hooker: "Some of my relations say it cannot *possibly* be ————'s article, because the review speaks so very highly of ———. Poor dear simple folk." To Gray he wrote regarding the review quoted below: 'Your review seems to me *admirable;* by far the best that I have read,' and again to Wallace 'Asa Gray fights like a hero in defence.' Huxley also says that Gray 'fought the battle splendidly in the United States,' and ranks him with Hooker, Lubbock and himself. Gray's review in the 'American Journal' and his series of articles in the 'Atlantic Monthly' seem at this time, however, rather colorless and chiefly concerned in arguing that if evolution is true it does not conflict with natural theology.—EDITOR.

smother it with ridicule or to crush it by vehemence of denunciation. 'The struggle for existence,' and 'Natural selection,' have become household words and every-day conceptions. The reality and the importance of the natural processes on which Darwin founds his deductions are no more doubted than those of growth and multiplication; and, whether the full potency attributed to them is admitted or not, no one doubts their vast and far-reaching significance. Wherever the biological sciences are studied, the 'Origin of Species' lights the paths of the investigator; wherever they are taught it permeates the course of instruction. Nor has the influence of Darwinian ideas been less profound, beyond the realms of Biology. The oldest of all philosophies, that of Evolution, was bound hand and foot and cast into utter darkness during the millennium of theological scholasticism. But Darwin poured new life-blood into the ancient frame; the bonds burst, and the revivified thought of ancient Greece has proved itself to be a more adequate expression of the universal order of things than any of the schemes which have been accepted by the credulity and welcomed by the superstition of seventy later generations of men.

To any one who studies the signs of the times, the emergence of the philosophy of Evolution, in the attitude of claimant to the throne of the world of thought, from the limbo of hated and, as many hoped, forgotten things, is the most portentous event of the nineteenth century. But the most effective weapons of the modern champions of Evolution were fabricated by Darwin; and the 'Origin of Species' has enlisted a formidable body of combatants, trained in the severe school of Physical Science, whose ears might have long remained deaf to the speculations of *à priori* philosophers. * * *

If I confine my retrospect of the reception of the 'Origin of Species' to a twelvemonth, or thereabouts, from the time of its publication, I do not recollect anything quite so foolish and unmannerly as the 'Quarterly Review' article, unless, perhaps, the address of a Reverend Professor to the Dublin Geological Society might enter into competition with it. But a large proportion of Mr. Darwin's critics had a lamentable resemblance to the 'Quarterly' reviewer, in so far as they lacked either the will, or the wit, to make themselves masters of his doctrine; hardly any possessed the knowledge required to follow him through the immense range of biological and geological science which the 'Origin' covered; while, too commonly, they had prejudiced the case on theological grounds, and, as seems to be inevitable when this happens, eked out lack of reason by superfluity of railing.

But it will be more pleasant and more profitable to consider those criticisms, which were acknowledged by writers of scientific authority, or which bore internal evidence of the greater or less competency and, often, of the good faith, of their authors. Restricting my survey to a

twelvemonth, or thereabouts, after the publication of the 'Origin,' I find among such critics Louis Agassiz; Murray, an excellent entomologist; Harvey, a botanist of considerable repute; and the author of an article in the 'Edinburgh Review,' all strongly adverse to Darwin. Pictet, the distinguished and widely learned paleontologist of Geneva, treats Mr. Darwin with a respect which forms a grateful contrast to the tone of some of the preceding writers, but consents to go with him only a very little way. On the other hand, Lyell, up to that time a pillar of the anti-transmutationists (who regarded him, ever afterwards, as Pallas Athene may have looked at Dian, after the Endymion affair), declared himself a Darwinian, though not without putting in a serious *caveat*. Nevertheless, he was a tower of strength, and his courageous stand for truth as against consistency, did him infinite honour. As evolutionists, *sans phrase*, I do not call to mind among the biologists more than Asa Gray, who fought the battle splendidly in the United States; Hooker, who was no less vigorous here; the present Sir John Lubbock and myself.

DARWIN ON THE ORIGIN OF SPECIES.*

Such are the signs of defective information which contribute, almost at each chapter, to check our confidence in the teachings and advocacy of the hypothesis of 'Natural Selection.' But, as we have before been led to remark, most of Mr. Darwin's statements elude, by their vagueness and incompleteness, the test of Natural History facts. Thus he says:—

'I think it highly probable that our domestic dogs have descended from several wild species.' It may be so; but what are the species here referred to? Are they known, or named, or can they be defined? If so, why are they not indicated, so that the naturalist might have some means of judging of the degree of probability, or value of the surmise, and of its bearing on the hypothesis?

'Isolation, also,' says Mr. Darwin, 'is an important element in the process of natural selection.' But how can one select if a thing be 'isolated'? Even using the word in the sense of a confined area, Mr. Darwin admits that the conditions of life 'throughout such area, will tend to modify all the individuals of a species in the same manner, in relation to the same conditions.' (P. 104.)

No evidence, however, is given of a species having ever been created in that way; but granting the hypothetical influence and transmutation, there is no selection here. The author adds, 'Although I do not doubt that isolation is of considerable importance in the production of new species, on the whole, I am inclined to believe, that largeness

* From an article in the 'Edinburgh Review' for April, 1860, attributed to Richard Owen.

of area is of more importance in the production of species capable of spreading widely. (P. 105.)

Now, on such a question as the origin of species, and in an express, formal, scientific treatise on the subject, the expression of a belief, where one looks for a demonstration, is simply provoking. We are not concerned in the author's beliefs or inclinations to believe. Belief is a state of mind short of actual knowledge. It is a state which may govern action, when based upon a tacit admission of the mind's incompetency to prove a proposition, coupled with submissive acceptance of an authoritative dogma, or worship of a favorite idol of the mind. We readily concede, and it needs, indeed, no ghost to reveal the fact, that the wider the area in which a species may be produced, the more widely it will spread. But we fail to discern its import in respect of the great question at issue.

We have read and studied with care most of the monographs conveying the results of close investigations of particular groups of animals, but have not found, what Darwin asserts to be the fact, at least as regards all those investigators of particular groups of animals and plants whose treatises he has read, viz., that their authors 'are one and all firmly convinced that each of the well-marked forms or species was at the first independently created.' Our experience has been that the monographers referred to have rarely committed themselves to any conjectural hypothesis whatever, upon the origin of the species which they have closely studied.

Darwin appeals from the 'experienced naturalists whose minds are stocked with a multitude of facts' which he assumes to have been 'viewed from a point of view opposite to his own,' to the 'few naturalists endowed with much flexibility of mind,' for a favourable reception of his hypothesis. We must confess that the minds to whose conclusions we incline to bow belong to that truth-loving, truth-seeking, truth-imparting class, which Robert Brown, Bojanus, Rudolphi, Cuvier, Ehrenberg, Herold, Kölliker, and Siebold, worthily exemplify. The rightly and sagaciously generalizing intellect is associated with the power of endurance of continuous and laborious research, exemplarily manifested in such monographs as we have quoted below. Their authors are the men who trouble the intellectual world little with their beliefs, but enrich it greatly with their proofs. If close and long-continued research, sustained by the determination to get accurate results, blunted, as Mr. Darwin seems to imply, the far-seeing discovering faculty, then are we driven to this paradox, viz., that the elucidation of the higher problems, nay the highest, in Biology, is to be sought for or expected in the lucubrations of those naturalists whose minds are not weighted or troubled with more than a discursive and superficial knowledge of nature.

PROFESSOR AGASSIZ ON THE ORIGIN OF SPECIES.*

Since the arguments presented by Darwin in favor of a universal derivation from one primary form, of all the peculiarities existing now among living beings have not made the slightest impression on my mind, nor modified in any way the views I have already propounded, I may fairly refer the reader to the paragraphs alluded to above as containing sufficient evidence of their correctness, and I will here only add a single argument, which seems to leave the question where I have placed it.

It seems to me that there is much confusion of ideas in the general statement of the variability of species so often repeated lately. If species do not exist at all, as the supporters of the transmutation theory maintain, how can they vary? and if individuals alone exist, how can the differences which may be observed among them prove the variability of species? The fact seems to me to be that while species are based upon definite relations among individuals which differ in various ways among themselves, each individual, as a distinct being, has a definite course to run from the time of its first formation to the end of its existence, during which it never loses its identity nor changes its individuality, nor its relations to other individuals belonging to the same species, but preserves all the categories of relationship which constitute specific or generic or family affinity, or any other kind or degree of affinity. *To prove that species vary it should be proved that individuals born from common ancestors change the different categories of relationship which they bore primitively to one another.* While all that has thus far been shown is, that there exists a considerable difference among individuals of one and the same species. This may be new to those who have looked upon every individual picked up at random, as affording the means of describing satisfactorily any species; but no naturalist who has studied carefully any of the species now best known, can have failed to perceive that it requires extensive series of specimens accurately to describe a species, and that the more complete such series are, the more precise appear the limits which separate species. Surely the aim of science cannot be to furnish amateur zoölogists or collectors a *recipe* for a ready identification of any chance specimen that may fall into their hands. And the difficulties with which we may meet in attempting to characterize species do not afford the first indication that species do not exist at all, as long as most of them can be distinguished, as such, almost at first sight. I foresee that some convert to the transmutation creed will at once object that the facility with which species may be distinguished is no evidence that they were not derived from other species. It may be so.

* From a review in 'The American Journal of Science and Arts,' July, 1860.

But as long as no fact is adduced to show that any one well-known species among the many thousands that are buried in the whole series of fossiliferous rocks, is actually the parent of any one of the species now living, such arguments can have no weight; and thus far the supporters of the transmutation theory have failed to produce any such facts. Instead of facts we are treated with marvelous bear, cuckoo, and other stories. Credat Judaeus Apella!

Had Mr. Darwin or his followers furnished a single fact to show that individuals change, in the course of time, in such a manner as to produce at last species different from those known before, the state of the case might be different. But it stands recorded now as before, that the animals known to the ancients are still in existence, exhibiting to this day the characters they exhibited of old. The geological record, even with all its imperfections, exaggerated to distortion, tells now, what it has told from the beginning, that the supposed intermediate forms between the species of different geological periods are imaginary beings, called up merely in support of a fanciful theory. The origin of all the diversity among living beings remains a mystery as totally unexplained as if the book of Mr. Darwin had never been written, for no theory unsupported by fact, however plausible it may appear, can be admitted in science.

It seems generally admitted that the work of Darwin is particularly remarkable for the fairness with which he presents the facts adverse to his views. It may be so; but I confess that it has made a very different impression upon me. I have been more forcibly struck by his inability to perceive when the facts are fatal to his argument, than by anything else in the whole work. His chapter on the Geological Record, in particular, appears to me, from beginning to end, as a series of illogical deductions and misrepresentations of the modern results of Geology and Palæontology. I do not intend to argue here, one by one, the questions he has discussed. Such arguments end too often in special pleading, and any one familiar with the subject may readily perceive where the truth lies by confronting his assertions with the geological record itself. But since the question at issue is chiefly to be settled by palæontological evidence, and I have devoted the greater part of my life to the special study of the fossils, I wish to record my protest against his mode of treating this part of the subject. Not only does Darwin never perceive when the facts are fatal to his views, but when he has succeeded by an ingenious circumlocution in overleaping the facts, he would have us believe that he has lessened their importance or changed their meaning.

REVIEW OF DARWIN'S THEORY ON THE ORIGIN OF SPECIES BY MEANS OF NATURAL SELECTION.

BY ASA GRAY.*

We are thus, at last, brought to the question; what would happen if the derivation of species were to be substantiated, either as a true physical theory, or as a sufficient hypothesis? What would come of it? The enquiry is a pertinent one, just now. For, of those who agree with us in thinking that Darwin has not established his theory of derivation, many will admit with us that he has rendered a theory of derivation much less improbable than before; that such a theory chimes in with the established doctrines of physical science, and is not unlikely to be largely accepted long before it can be proved. Moreover, the various notions that prevail,—equally among the most and the least religious,—as to the relations between natural agencies or phenomena and Efficient Cause, are seemingly more crude, obscure, and discordant than they need be.

It is not surprising that the doctrine of the book should be denounced as atheistical. What does surprise and concern us is, that it should be so denounced by a scientific man, on the broad assumption that a material connection between the members of a series of organized beings is inconsistent with the idea of their being intellectually connected with one another through the Deity, *i. e.*, as products of one mind, as indicating and realizing a preconceived plan. An assumption the rebound of which is somewhat fearful to contemplate, but fortunately one which every natural birth protests against. * * *

We wished under the light of such views, to examine more critically the doctrine of this book, especially of some questionable parts;—for instance, its explanation of the natural development of organs, and its implication of a "necessary acquirement of mental power" in the ascending scale of gradation. But there is room only for the general declaration that we cannot think the Cosmos a series which began with chaos and ends with mind, or of which mind is a result; that if by the successive origination of species and organs through natural agencies, the author means a series of events which succeed each other irrespective of a continued directing intelligence,—events which mind does not order and shape to destined ends,—then he has not established that doctrine, nor advanced towards its establishment, but has accumulated improbabilities beyond all belief. Take the formation and the origination of the successive degrees of complexity of eyes as a specimen. The treatment of this subject (pp. 188, 189), upon one interpretation is open to all the objections referred to; but if, on the other

* From a review in 'The American Journal of Science and Arts,' March, 1860.

hand, we may rightly compare the eye "to a telescope, perfected by the long continued efforts of the highest human intellects," we could carry out the analogy, and draw satisfactory illustrations and inferences from it. The essential, the directly intellectual thing is the making of the improvements in the telescope or the steam-engine. Whether the successive improvements, being small at each step, and consistent with the general type of the instrument, are applied to some of the individual machines, or entire new machines are constructed for each, is a minor matter. Though if machines could engender, the adaptive method would be most economical; and economy is said to be a paramount law in nature. The origination of the improvements, and the successive adaptations to meet new conditions or subserve other ends, are what answer to the supernatural, and therefore remain inexplicable. As to bringing them into use, though wisdom foresees the result, the circumstances and the natural competition will take care of that, in the long run. The old ones will go out of use fast enough, except where an old and simple machine remains still best adapted to a particular purpose or condition,—as, for instance, the old Newcomen engine for pumping out coal-pits. If there's a Divinity that shapes these ends, the whole is intelligible and reasonable; otherwise, not.

We regret that the necessity of discussing philosophical questions has prevented a fuller examination of the theory itself, and of the interesting scientific points which are brought to bear in its favor. One of its neatest points, certainly a very strong one for the local origination of species, and their gradual diffusion under natural agencies, we must reserve for some other convenient opportunity.

The work is a scientific one, rigidly restricted to its direct object; and by its science it must stand or fall. Its aim is, probably not to deny creative intervention in nature,—for the admission of the independent origination of certain types does away with all antecedent improbability of as much intervention as may be required,—but to maintain that Natural Selection in explaining the facts, explains also many classes of facts which thousand-fold repeated independent acts of creation do not explain, but leave more mysterious than ever. How far the author has succeeded, the scientific world will in due time be able to pronounce.

SCIENTIFIC LITERATURE.

THE AGRICULTURAL YEARBOOK.

THE Yearbook of the United States Department of Agriculture has taken rank as one of the important annuals of this country, and in point of circulation is hardly equaled. This is due to the munificence of the Federal Government in appropriating $300,000 annually for its publication, in an edition of half a million copies, and to the care which is given by the Department of Agriculture to the preparation of timely and interesting articles and appropriate illustrations. The Yearbook takes the place of the annual report of the Secretary, which was naturally a more formal document and less likely to attract the average reader's attention. In its present form it presents an attractive appearance, and its many illustrations and long list of short articles on a variety of subjects invite attention. The volume for 1900 comprises nearly nine hundred pages, and is illustrated by eighty-seven plates, nine of them colored, and eighty-eight text figures. In addition to the executive reports, which occupy less than eighty pages, it contains thirty-one articles on various phases of the Department's work or other subjects of direct interest to agriculture. Only a part of these can be mentioned, but enough to indicate the range of subjects and that the volume is not alone of interest and value to the farmers of the country. In an article on Smyrna fig culture in the United States, Dr. Howard describes the successful introduction by the Department of the Blastophaga, the insect which fertilizes the fig and has enabled the production of Smyrna figs of good quality in this country; and one on the date palm tells what has been done for the promotion of that industry by the introduction of the best varieties into Arizona, where it flourishes even in soils heavily impregnated with alkali. Wheat growing in the semi-arid districts has been rendered less uncertain, it is thought, by the introduction of macaroni and several other varieties of wheat, which have already given promise. Articles on the food of nestling birds and how birds affect the orchard illustrate the practical bearings of a phase of work which is concerned with the food habits of birds under different conditions, to ascertain what kinds are beneficial and what injurious to the farmer and fruit grower; while one on the food value of the potato gives some practical results of the work of the Department in another direction. There are two articles on practical forestry and forest extension, several on injurious insects and their repression, a helpful one on practical irrigation, two on road building, in which subject the Department is taking an active interest, and two on meteorology. One of the latter, on hot waves, the conditions which produce them and their effects on agriculture, is of special interest even though it does not suggest any relief. The free rural delivery of mails, although in no way connected with the Department of Agriculture, comes so close to its farmer constituents that an account of the working of that system does not seem out of place in its Yearbook. The four thousand routes now in operation provide for the daily delivery of mail at the scattered homes of about three and a half million of rural population. The work done in a long life devoted to agriculture, horticulture and kindred subjects by the late William Saunders, who had been connected with the Department since its establishment in 1862, is the subject of a short sketch,

and his portrait occupies the place of honor as the frontispiece to the volume. An appendix of over 200 pages contains a vast amount of condensed information on a variety of subjects, and bears out the inference that no effort has been spared to make this, like the preceding volumes, worthy of the large expenditure involved and the wide distribution it is given.

METEOROLOGY.

A well-arranged, readable and generally satisfactory presentation of the principles of meteorology may be found in the latest text-book on that subject, Börnstein's *Leitfaden der Wetterkunde.* The general plan of the book is conventional, but there are one or two features which deserve special mention. In the introduction an interesting figure shows the 'thermo-isopleths' for Berlin, these lines indicating, in one drawing, both the diurnal and the annual march of the air temperature. In the chapter on temperature all important matters are considered, including the recent work of Pettersson and Meinardus on long-range forecasts for Europe based on the special characteristics of the Gulf Stream, and a brief summary of the meteorological results of the international balloon ascents, in some of which the author took part. The physiological effects of atmospheric humidity receive some consideration, and a new table is given showing, for a number of stations, the probable fall of temperature below the wet-bulb reading of an afternoon hour, to be expected during the night. This table is useful in predicting frost. The much-agitated question of hail prevention by cannon firing is briefly taken up in the sections on rainfall. The chapter on weather is very complete. Thunderstorm charts and theories; the weather types of van Bebber and Köppen, and the weather services of the world, are all discussed, the weather types being fully illustrated. A noteworthy feature of the work is the nine colored views of cloud types, similar to those in the International Cloud Atlas. This is the first text-book to have such elaborate illustrations of clouds. A fairly good working bibliography is appended, which includes comparatively few works in English. The index is good, but the chapters are not numbered, and there are no section headings in the text.

PSYCHOLOGY.

'An Introduction to Psychology,' by Mary Whiton Calkins (The Macmillan Company), is one of the text-books in psychology that makes it obvious that psychology is to a great extent all things to all men. The books do not present the same body of accepted truth, varying only in such matters as arrangement and adaptation to students of different capacities and different practical needs. Changing your psychology book is not so much changing your coat as changing your skin. Miss Calkins, for instance, includes the study of 'the conscious relation of the human self to a divine self' as a sample of certain mysterious relationships between selves apart from those due to physical agencies. She includes a sympathetic discussion of the phenomena of telepathy and veridical hallucinations. Many of her co-workers would rigorously exclude both these topics. She makes no mention of the instructive reactions which are the *fons et origo* of our later intellects and wills or of the law of habit which would seem to many to be the key to comprehension of mental processes. Yet Miss Calkins's book is as scholarly and fair an exposition of the elements of psychology as any of the recent books. Those who seek from psychology training in analysis and discrimination and approach the study from an interest in general philosophy will find it a particularly helpful manual.

THE PROGRESS OF SCIENCE.

PROFESSOR RUDOLF VIRCHOW.

THE eightieth birthday of one of the leaders of modern civilization has been celebrated with imposing ceremonies at Berlin. Virchow is the founder of the science of pathology, and his services for anthropology have been nearly as great. He has not only demonstrated that the scientific research of the laboratory may be directly beneficial to mankind, but he has himself applied his own discoveries for the welfare of Berlin and of the German army, whence they have extended to the whole world. There is no city whose inhabitants are not healthier and happier because Virchow has lived and worked; it is indeed scarcely an exaggeration to say that there is no patient of any village physician who does not benefit from the labors of this man whose name he may never have heard. Virchow often stood opposed to Bismarck; in written history the iron chancellor may always be the more frequently named, but the world's progress has probably been more directly led by the man of science.

The ceremonies at Berlin included the presentation of a marble bust of Virchow to the great Pathological Institute founded by him; the presentation of an additional endowment to the Virchow Fund for the promotion of research, toward which the municipality contributed $20,000; the presentation of addresses of congratulation on behalf of the empire, state and municipality, and from national and foreign institutions, and, most interesting of all, a lecture by Virchow on the history and scope of pathology. Lord Lister, who represented the Royal Society and other British institutions, said: "All these bodies join in recognition of your gigantic intellectual powers, in gratitude for the great benefits that you have conferred upon humanity, and in admiration of your personal character, your absolute uprightness, the courage which has enabled you always to advocate what you believed to be the cause of truth, liberty and justice, and the genial nature which has won for you the love of all who know you. The astonishing vigor which you displayed in the address to which we listened to-day justifies the hope that, when many of us your juniors shall have been removed from this scene of labor, it may be granted to you to celebrate your ninetieth birthday not only in health and honor but in continued activity in the service of mankind."

THE YALE BICENTENNIAL EXERCISES.

UNIVERSITIES are among the most stable of institutions. Glasgow University recently celebrated its ninth jubilee, while Harvard University commemorated in 1886 the two hundred and fiftieth anniversary of its foundation. Yale University, the third in age of our American colleges, is now two hundred years old and the event has been celebrated in a manner commensurate with the prestige of the institution. Such occasions are almost medieval in their gowned processions, the presentation of Latin addresses, the conferring of degrees and the like; but they are nearly as modern as football games, in so far as they serve as an occasion of collecting endowments, attracting students and arousing the loyalty of alumni. Both in its dramatic exhibition and in its financial outcome the celebration at New Haven was eminently successful. There were

present thousands of graduates and guests for whom a program lasting four days had been prepared. It included sermons, addresses, concerts, dedications and other exercises, leading to the commemorative exercises and the conferring of honorary degrees. The doctorate of laws was conferred on President Roosevelt and forty-six others, including among scientific men J. S. Billings, director of the New York Public Library; S. P. Langley, secretary of the Smithsonian Institution; A. A. Michelson, professor of physics in the University of Chicago; William Osler, professor of medicine in the Johns Hopkins Medical School; Henry Smith Pritchett, president of the Massachusetts Institute of Technology; Ira Remsen, president of the Johns Hopkins University; Ogden Nicholas Rood, professor of physics in Columbia University, and Wilhelm Waldeyer, professor of anatomy in the University of Berlin.

About half of those who have become eminent for public services are college graduates, and Yale has certainly contributed its full share. The addresses by ex-President Gilman on Yale's Relation to Letters and Science, and by Professor Welch on Yale's Relation to Medicine, told of the important part taken by Yale's graduates in the scientific work of the country. Through the influence of the elder Silliman and the 'American Journal of Science,' established by him in 1818, and through the Sheffield Scientific School, Yale has always led in the sciences. Its faculty has included the two Sillimans, Olmsted, Loomis, Dana, Newton and Marsh, and among its alumni are many of those who have advanced science, including two of our leading inventors, Whitney and Morse. In education Yale has had great influence through the college presidents it has trained. As President Northrop pointed out in his address, one hundred and five graduates of Yale have been president of a college; and eighty-five different colleges have at some time had a Yale graduate for president. Yale furnished the first president of at least seventeen colleges—Princeton, Columbia, Dartmouth, Georgia, Williams, Hamilton, Kenyon, Illinois, Wabash, Missouri, Wisconsin, Beloit, California, Cornell, Western Reserve, Johns Hopkins and Chicago.

NOTES FROM THE BERLIN MEETING OF THE INTERNATIONAL ZOOLOGICAL CONGRESS.

The fifth meeting of the International Zoological Congress, which opened at Berlin on August 13, was attended by a very large number of zoologists and carried out an elaborate program in the course of which many highly interesting papers were read. The general sessions of the Congress were occupied by a series of addresses on general topics, among which may be mentioned those of Professor Yves Delage, of Paris on the fertilization of the egg, of Professor Grassi of Rome on the malaria organism, of Professor Poulton of Oxford on mimicry in insects, and the fine closing address on vitalism and mechanism by Professor Bütschli of Heidelberg. The number of detailed papers read in the various sections is too great to allow of their review here, but attention may be called to the interesting discussion on vitalism and mechanism that took place in the opening session of the section for experimental biology. The modern revival of interest in this time-honored problem, which occupied so large a field of discussion a half-century ago, has been largely due to the surprising results attained by experimental embryology during the last decade, especially those brought forward by Roux, Driesch and their many followers. The discussion at Berlin was opened by Driesch himself in a paper entitled 'Two New Proofs of Vitalism,' a title which indicates his own position on the general problem. Presenting in brief

form the essential arguments that he had already put forward in more extended papers on the development of fractional parts of the egg and on the general problem of the localization of morphogenic processes, Driesch maintained that these processes have no true analogue in the inorganic world, are insoluble by any purely mechanical or physico-chemical hypothesis, and hence form a problem *sui generis*. The most characteristic operations of the living organism, more especially those concerned in the processes of regeneration, regulation and the like, fail of adequate interpretation on the so-called 'machine-theory' of life, and must be regarded from a vitalistic as opposed to a mechanistic standpoint. His conclusions, which were stated with great lucidity and force, met with strong opposition in the animated controversy that followed, in which a number of eminent embryologists participated. Some of these speakers wholly denied the validity of Driesch's reasoning and endeavored to show that true analogues to regulative phenomena occur in purely physical processes. Others, notably Professor Roux, took more cautious ground, maintaining that despite our present inability to explain or even to conceive the nature of some of the most striking and characteristic phenomena of development, we are by no means justified in taking refuge behind such a word as 'vitalism,' which carries with it so many misleading connotations from the earlier period when it was employed in connection with the exploded hypothesis of a specific 'vital force.'

The masterly and scholarly address of Professor Bütschli, delivered before the general session, contained not only a specific examination of the main facts in which Driesch's position rests, but also a critical study of more abstract conceptions, such as those embodied in the words 'mechanism,' 'causality' and the like, which are inevitably involved in the discussion of the subject. This address, which has been published in pamphlet form by Engelmann of Leipzig under the title *Mechanism and Vitalism* is worthy of attentive study, not only by students of zoology, but also by all who are interested in the more general aspects of scientific progress. Recognizing the difficulties that the mechanistic interpretation of organic nature has to encounter, Bütschli nevertheless expresses the judgment that, in the broad sense of the phrase, it is the only one under which scientific investigation is possible, and that it is, to say the least, wholly premature to speak of 'proofs of vitalism.' "The phenomena involved in the localization process seem to me not to differ fundamentally in kind from those occurring in the inorganic world." The acceptance of vitalistic hypothesis constitutes a backward step in scientific method. "Both the old and the new vitalism have done no more than to emphasize the unsolved riddles that confront us and to throw doubt on the possibility of their explanation on a mechanistic basis. The assumption of vitalistic processes involves the admission that they are ultimate phenomena, in themselves inexplicable, that we are not able to subsume under general laws. Hence we must take the ground that in vital phenomena we can comprehend only that which may receive a physico-chemical explanation." How far the mechanistic hypothesis will succeed in the explanation of vital phenomena, only the future will show. 'By their fruits ye shall know them.'

In considering the possibility of a mechanistic explanation of the purposive or teleological aspect of living organisms Bütschli recognizes Darwin's theory of natural selection as the sole fruitful attempt in this direction. In view of the difficulties that have been urged against that theory, and especially the drastic criticism it has received at the hands of some German writers, it is interesting to find that

so competent and critical an authority as Bütschli accepts Darwin's explanation, as amplified by later workers, not only as a possible one, but also as the most probable one thus far advanced.

THE EFFECT OF SECULAR COOLING AND METEORIC DUST ON THE LENGTH OF THE DAY.

It is well known that the day, or interval required for one complete rotation of the earth, is the time unit by which the succession of terrestrial and celestial events is measured. The earth revolves with a regularity which far surpasses that of the best clocks and chronometers except for short intervals of time, such as a few minutes, or a few hours at most. But it is not certain that the day has been of the same length in the remote past as at present, or that it will remain of the same length in the distant future. It is therefore a matter of prime importance, especially in those branches of astronomy which deal with long intervals of time, to understand the effects of such secular causes as may tend to modify the length of the day. In a recent number of the 'Astronomical Journal' Professor R. S. Woodward has published a mathematical investigation of the effects of secular cooling and of accumulations of meteoric dust. The cooling, and consequent cubical contraction, of the earth tends to shorten the day; while the increment to the earth's mass from meteorites, of which not less than twenty millions daily fall into the atmosphere, tends to lengthen the day.

The effect of secular cooling was considered to a limited extent by Laplace in his 'Mécanique céleste.' Assuming that the earth is in the last stages of cooling he reached the conclusion that the length of the day has not changed appreciably in the past two thousand years. Without making any assumption as to the present stage in the history of cooling, Woodward shows that during no interval so short as twenty centuries in the entire history of cooling can the length of the day change by so much as a thousandth of a second from the cause in question. In fact, so slowly does the effect of secular cooling accumulate that the day will not change, or has not changed, as the case may be, by so much as a half second in the first ten million years after the earth began to solidify and to lose heat by conduction through its crust. On the other hand, the shortening of the day which must come with the end of the process of cooling is a very sensible fraction of its present length. For this total effect Woodward gives a remarkably simple expression, namely: the ratio of the change in length of the day to its initial length is equal to two-thirds of the product of the fall in temperature of the earth by its cubical contraction. Supposing the earth to have been initially at a temperature of 3000°C., and that its cubical contraction is the same as that of iron, or about $3x10^{-5}$, it follows that the day will be ultimately shortened by about six per cent. of its initial length, or by an hour and a half nearly. The length of time required by the earth to cool down sensibly to the temperature of surrounding space is very great. Nothing short of a million years is suitable as a time unit for measuring the historical progress of such events. Thus Woodward shows that it will require about three hundred thousand million years for the earth to accomplish ninety-five per cent. of its contraction, and that after a million million years its contraction would no longer sensibly affect the length of the day.

To what extent is this shortening of the day due to contraction offset by the lengthening due to accessions of meteoric dust? The calculation shows that the accumulation of such dust goes on so slowly that its effect will not become perceptible until the total effect from secular cooling is nearly complete. In round numbers, the latter effect goes on two hundred thousand times as

fast as the opposite effect from meteoric dust. In fact, if the average mass of meteorites is no greater than one gram, it will require a million million years, at the present rate of influx, to lengthen the day by so much as a quarter of a second.

It is clear, therefore, that, if the regularity of the earth as a timekeeper during historic times is to be questioned, one must look to other causes than secular cooling and meteoric dust.

ENGLAND'S CHEMICAL INDUSTRY.

There has been much agitation in England during the last few years over the fact that Germany is steadily forging ahead in all lines of chemical industry. As long ago as 1886, Professor Mendola, in a paper read before the Society of Arts, reviewed the English color industry, and sounded a warning note regarding its future progress. English manufacturers have, however, manfully stood by their old methods, and are seeing their trade gradually, but surely slipping from their grasp.

At the Glasgow meeting of the British Association, Arthur C. Green, who is well qualified to speak on the subject, read a paper on the relative progress of the coal-tar industry in England and Germany during the last fifteen years, in which he handles the matter with almost brutal frankness. After sketching the wonderful advancement which has been made in the development of the industry during the period covered by his paper, the discovery of thousands of new dyestuffs, the introduction of hundreds of new synthetic pharmaceutical products and the great advances in the production and design of chemical plant, occasioned by the vast requirements of the industry, he brings out the comparative statistics of the industry in the two countries. Among them the following are worthy of reproduction. The exports of coal-tar colors, exclusive of alizarin, from Germany have increased from 4,646 tons in 1885 to 17,639 tons in 1899; those of anilin oil and salt from 1,713 tons in 1885 to 7,135 in 1895, and of alizarin colors from 4,284 to 8,927 tons in the same period. The values of the coal-tar colors exported increased from 2,600,000 pounds sterling in 1894 to 3,500,000 pounds in 1898. In fifteen years the imports of coal-tar dyestuffs into England have increased fifty per cent., while the exports from England have decreased over thirty per cent. The Bradford Dyers' Association uses at present 80% German coloring-matters and only 10% English. The British Cotton and Wool Dyers' Association imports 78% of its anilin colors and over 98% of its alizarin colors. The English Sewing Cotton Company used, out of a total of sixty tons of coloring-matters, only 9% of English manufacture. In addition to this, the indigo industry, which now yields to India an income of three million pounds sterling a year, is seriously threatened by the synthetic indigo from Germany, and its days are in all probability numbered.

The cause of this state of affairs Mr. Green finds in the almost utter inappreciation of science on the part of the English Government, manufacturers and people. As he says, 'it is not so much the education of our chemists which is at fault as the scientific education of the public as a whole.'

This theme has more than an indirect bearing upon American industries. We are just beginning to reap the harvest which awaits us in the application of scientific principles to our industries. Until recently we have been following the English 'rule o' thumb' method, but along many lines there has now been a radical change, and in these England is finding her commercial supremacy threatened from this side of the water. There are yet enormous fields for us to conquer, in which we have a great advantage over Germany in the natural resources of the country. The enormous industrial strides which this country is taking,

which command the admiration as well as the fear of the world, are after all the fruitage of the ideas which the teachers of science in our colleges and technological schools have been pounding into the often unwilling brains of their students during the last quarter of a century.

SCIENTIFIC ITEMS.

Dr. Richmond Mayo-Smith, professor of political economy and social science at Columbia University died as the result of a fall on November 11.—A memorial meeting in honor of the late Henry Augustus Rowland was held at the Johns Hopkins University, on October 16. The principal address was made by Dr. T. C. Mendenhall.

The Rumford medals of the American Academy of Arts and Sciences have been presented to Professors Carl Barus and Elihu Thomson.—Professor Geo. J. Brush, emeritus professor of mineralogy and formerly director of the Sheffield Scientific School of Yale University, received a loving cup from his former students, on the occasion of the recent bicentennial exercises.

The second annual Huxley lecture of the Anthropological Institute was delivered by Dr. Francis Galton, F.R.S., on October 29, his subject being 'The Possible Improvement of the Human Breed under the Existing Conditions of Law and Sentiment.'

Professor Hugo Münsterberg, of Harvard University, began, on November 11, a series of eight Lowell lectures at the Massachusetts Institute of Technology, on 'The Results of Experimental Psychology.'

Mr. Andrew Carnegie has given an additional million dollars towards the endowment of the Carnegie Institute, Pittsburg, and a second million dollars for the Polytechnic Institute to be established in that city.—Mr. T. Jefferson Coolidge, late Minister to France, has given a fund of $50,000 to the Jefferson Physical Laboratory of Harvard University for physical research.—Mr. John D. Rockefeller has promised to contribute $200,000 toward the endowment fund for Barnard College, Columbia University, provided that an equal sum is given by others before January 1, 1902.—The preliminary plans have been accepted for a new building for the Department of Agriculture at Washington. These plans contemplate a marble structure, something over 300 feet long, with wings at either end extending to the rear to accommodate the various laboratories of the department.

THE POPULAR SCIENCE MONTHLY.

JANUARY, 1902.

THE MINNESOTA SEASIDE STATION.

By Professor CONWAY MACMILLAN,
UNIVERSITY OF MINNESOTA.

WHEN, in 1900, a tract of land on the Straits of Fuca was offered for the uses of a marine station to be operated in connection with the University of Minnesota, the transfer was made and the construction of a laboratory-camp begun. Previous and full information concerning the site had been received. It had been personally examined by a member of the University staff and had been highly commended. Being at the entrance of the Straits it was easily accessible to the Sound and to the open sea, while its littoral fauna and flora were known to be uncommonly interesting and rich both in species and individuals. One difficulty existed: there was no road from Port Renfrew to the laboratory site—a distance of about three miles. Consequently the whole matter was laid before the British Columbian Parliament then in session at Victoria, and through the assistance of the honorable members from the districts of Esquimalt and San Juan, with the approval of H. M. Commissioner of Works, a grant was obtained for a suitable road, work upon which was in progress during the summer of 1901.

In the initial movements incident to the establishment of the Station many Victorians were both interested and effective. From Sir Henri Joly de Lotbiniere, Lieutenant-Governor of the Province, to the humblest citizen there was received only the most uniform and delightful courtesy. To acknowledge so many kindnesses is indeed a pleasure, and to the members of the Government and of the Natural History Society of Victoria, and to all others who were of assistance sincere appreciation and thanks are due.

FIG. 1. BUILDINGS OF MINNESOTA SEASIDE STATION AS SEEN ACROSS STATION COVE. THE BUILDINGS FACE NEARLY SOUTH.

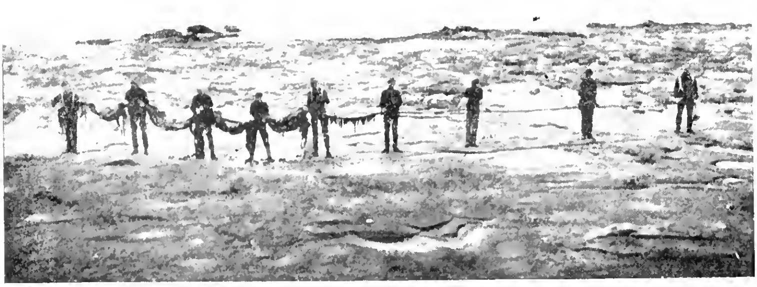


FIG. 2. GROUP OF STUDENTS HOLDING AN EXTENDED SPECIMEN OF THE GIANT KELP, NEREOCYSTIS PRIAPUS. JUST OFF SHORE A BED OF THIS KELP IS SHOWN.

The usefulness of a marine station on the Pacific as an adjunct to the laboratories of a university located far inland naturally needs no proclamation. During more than two decades, experience gained by American students at such points as Beaufort, Woods Holl, Cold Spring Harbor, Pacific Grove and elsewhere has demonstrated that the broadest and best foundations for a knowledge of morphology can not be laid without the assistance of instruction and research at the shore. More and more must the recognition of this fact become general, and with each succeeding year the number of serious students at the ocean-side and facilities for their work must increase and improve. That there should be stations upon both the eastern and the western coasts is imperative, and each will come to have its peculiar excellences and will develop its special lines of work. The eastern station has the advantages of accessibility while the western enjoys those of remoteness. At the laboratory on the eastern shore one may perhaps look for more conveniences and refinements; at that on the western coast one may expect more novelty and a greater openness and freedom of opportunity. To the student in the far west nothing can be more helpful than contact with the east: for the student in the east nothing is more to be desired than a sojourn in the west. Apparently, then, stations upon the Atlantic and Pacific coasts are alike desirable, and each with its own field of usefulness may be the complement of the other. Not only does the truth of this appear from the point of view of sound and broad instruction, but quite as impressively in connection with research. The living organisms of the two great oceans are by no means identical. To the student who turns his face from the Atlantic to the Pacific feeling that the New England or New Jersey shore has become somewhat trite and habitual, there is a fresh inspiration and enthusiasm to be derived from the coast of California or Vancouver.

One very distinct advantage enjoyed by a west coast station is the surpassing interest of the journey by which it is reached from a mid-continental or eastern point. While the tourist from Chicago to New York or Boston finds the journey swift and luxurious, he is passing through a relatively monotonous and uninteresting country. It is quite otherwise with the traveler from Minneapolis to Port Renfrew. In estimating the advantages of the Minnesota Seaside Station as an outpost of natural science and nature-study, there must certainly be taken into account not only its own immediate environment, but the route by which it is most conveniently reached from an eastern city. The journey over the Canadian Pacific, made in special cars and with the privilege of stopping at will, cannot be paralleled elsewhere on the continent. From the forest of central Minnesota the train speeds on through illimitable wheat-fields billowing and shimmering from horizon to horizon. It climbs from the valley of the Red river out upon the vast and lonely

plains of Assiniboia and swings westward, hour after hour, over the silent ranges furrowed everywhere by unnumbered feet of the departed herd. It rises to the foothills beyond Calgary and sights the white wall of the Rocky mountains a hundred miles away. It plunges through the Gap at Canmore, ascends the valley of the Bow between colossal peaks, crosses the continental divide at Laggan, drops down the canyon beside a foaming torrent to the mountain-girt valley of the Columbia, rises again mile after mile into the icy air of Rogers Pass amid the glaciers of the Selkirk summits and finds its way with the rushing waters of the

FIG. 3. FOOT OF THE GREAT GLACIER OF THE SELKIRKS.

Illicillewaet down to the Columbia again at Revelstoke. It hurries through echoing valleys, beside enchanting lakes, across ridges and chasms into the desert along the Thompson. It enters the historic valley of the Fraser and underneath frowning cliffs creeps down the reverberant gorge to the wonderful amphitheaters of Yale and Hope and finally reaches Vancouver and the sea. Then come the steamer voyages through the Straits of Georgia to Victoria and through the Straits of Fuca to Port Renfrew, and at last the invigorating walk through the forest or sturdy pull along the shore. To the lover of nature as well as to the serious student of ecology or plant distribution there is perhaps nowhere in the world a more inspiring and instructive journey of two thousand miles than this. It gives an opportunity of becoming

acquainted with the forests, the prairies, the plains, the foot-hills, the mountains, the glaciers, the deserts and the sea.

At such points as Lake Louise, where the mountain scenery is indescribably grand, there is an unequaled field for the study of talus-vegetation, the influence of the snow-line and the avalanche upon plant distribution and the characteristic population of mountain-park and meadow. Here one comes close to the wild life of the peaks, and far above the lake one may see the goats grazing upon their inaccessible crags or one may sometimes hear the roar of a grizzly rising distinct

FIG. 4. VIEW ON LAKE LOUISE SHOWING EFFECT OF SNOW SLIDES AND TALUS SLOPES ON THE DISTRIBUTION OF PLANTS.

above the clamor of the torrents. At Glacier the effect of ice-currents upon the growth and distribution of plants is most interestingly displayed. A series of photographs beginning just in front of the ice-mass and extending some hundreds of yards down the valley of the Illicillewaet shows at a glance how revegetation has proceeded, as the glacier has slowly and regularly retreated.

The exact situation of the Minnesota Seaside Station is in a little cove at the entrance of the Straits of Fuca, nearly opposite Cape Flattery, just outside the picturesque harbor of Port Renfrew and about sixty miles north of the city of Victoria. The west shore of Vancouver island is described in the old books of travel as a 'stern and rock-bound coast,' and it is indeed a perilous one for navigation. During much of

the year there is mist and fog to conceal the reefs and ledges and it has been the scene of many a tragedy of the sea since the old days of Drake and Ferrelo and the quest for the Northwest Passage. If the fog hangs low one may perhaps hear in the offing the sullen note of an Oriental liner as she feels her way into the Straits of Fuca, or if the skies are

FIG. 5. A VIEW OF THE SHORE AT LOW TIDE JUST IN FRONT OF THE SEASIDE STATION.

clear one may look across the water to the blue shores of Washington, indented by Neah and Clallam bays and prolonged westward into the ocean to the rock upon which stands Cape Flattery light. To the left rise the far-shining peaks of the Olympic mountains and, with a binocu-

FIG. 6. THE OLYMPIC MOUNTAINS AS SEEN ACROSS THE STRAITS OF FUCA, FROM THE NEIGHBORHOOD OF THE RACE ROCKS.

lar, glaciers can be seen upon their untrodden summits. When the Straits are flashing with the breeze, the picture of ocean, shore, forest and mountain is one of the most beautiful in the world, rivaling the

bay of Naples or the Adriatic and almost equaling the matchless Peruvian coast and the sea-front of Ecuador.

The log buildings of the Station stand in a small clearing and have an outlook upon the Straits and upon the Pacific. With the forest behind and the ocean in front their situation is as perfect scenically as it is for the purposes of science. Miles of tide-pools, reefs and kelp-covered rocks are easily accessible along the water front, while landward the hills rise to a height of nearly 3,000 feet. Four miles back are the mouths of the San Juan and Gordon rivers, both of which flow into Renfrew port and may be utilized as canoe routes towards the lakes and mountains of the interior. Over the whole country side spreads the primeval and well-nigh impenetrable forest of Vancouver with its gnarled yews, enormous cedars and towering spruces. On each side of

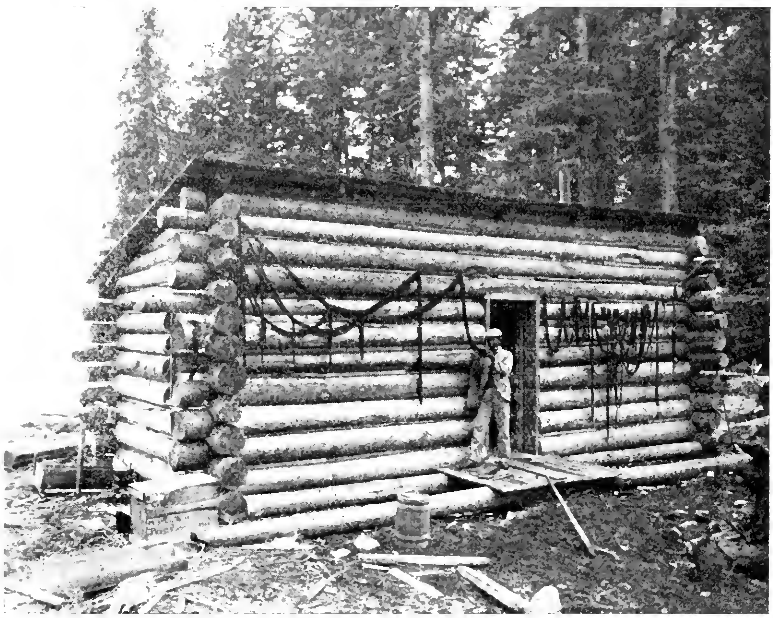


FIG. 7. 'THE FORMALOSE CLUB' THE ALGAE DRAPED OVER THE LOGS ARE EGREGIA AND NEREOCYSTIS.

the Station buildings a little rivulet comes down from the hills and the waters of the two mingle on the rocks just below high-tide mark. Altogether, the opportunity for the study of marine and coastal botany and zoology is magnificent, and there is no good reason why it should not be possible to maintain a thoroughly well-equipped international marine station at the entrance to the waters of Puget Sound. The location is altogether admirable, rich and interesting, and practical work has begun.

FIG. 8. A COVE ON THE WEST COAST NEAR THE STATION SHOWING SALAL BUSHES, ENTEROMORPHA FORMATION AND A STRONG ZONE OF FUCUS EVANESCENS. THE TREES IN THE CENTER CARRY LARGE MASSES OF EPIPHYTIC MOSSES.

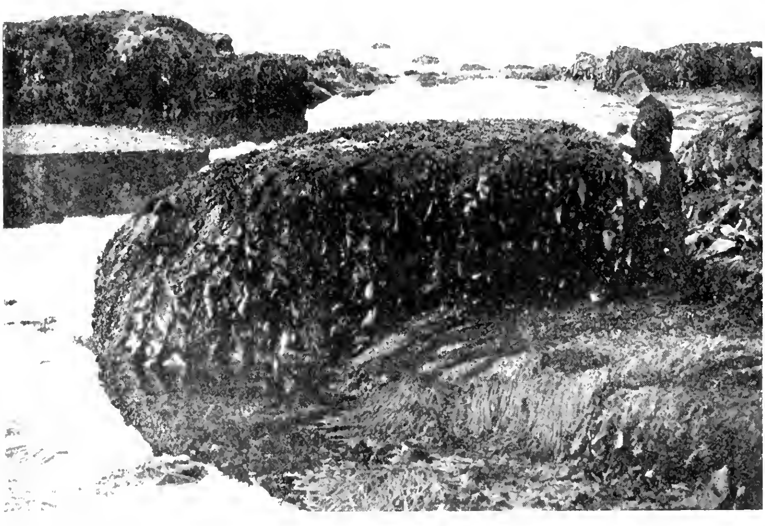


FIG. 9. KELP-COVERED ROCK SHOWING SPECIMENS OF EGREGIA, ALARIA AND HALOSACCION IN CHARACTERISTIC ATTITUDES. PHYLLOSPADIX SCOULERI APPEARS IN THE FOREGROUND.

At present the buildings of the Station number two and comprise a small house, 25 by 12 feet, on the shore, with a larger building, 60 by 25 feet, in the rear and on the higher ground. A third building is to be erected during the winter. Last summer, when a party of thirty-three went west from Minneapolis, it was apparent that the buildings would be inconveniently crowded, but by devoting half of the large living room to laboratory purposes it was possible to accommodate all who desired to work. The small house was used principally for microscopic work and for preservation of anatomical material. It received the name of the 'Formalose Club' from some ingenious members of the party. The large house is two stories in height and arranged for general camp purposes. Below, a transverse hallway divides the kitchen and storeroom from the

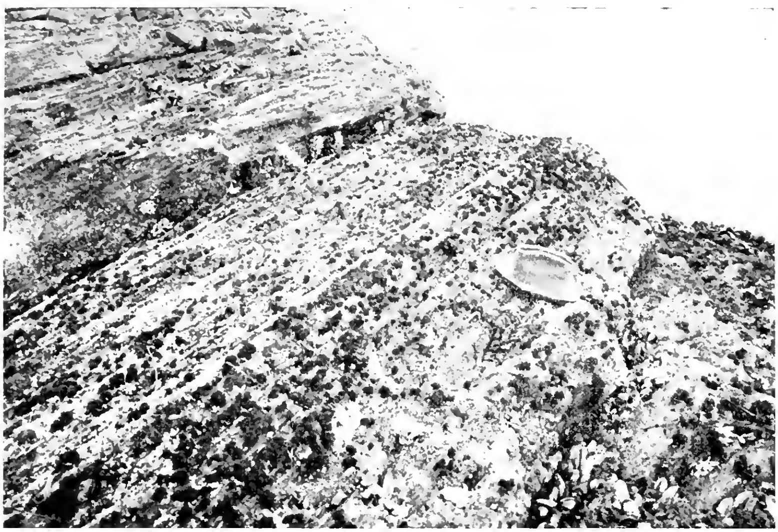


FIG. 10. FIELD OF ENDOCLADIA MURICATA ON SCHISTOSE ROCK TOGETHER WITH MUSSELS AND BARNACLES.

dining and living room. The latter with its large fireplace at the end and its festoons of flags and bunting in the University colors proved to be attractive and cheerful. Above, two large bunk rooms, one for men and one for women, afford the comforts of balsam beds to the weary, after the day's work is done.

Station equipment did not present a very serious problem during the first season. Most of the party preferred to devote their energies to the collection of material. However, some twelve or fifteen microscopes were in use, and both the small library and the store of chemicals and glassware were daily drawn upon.

In view of the many novel varieties and curious habits of the seaweeds they were the principal objects of study during the season of 1901.

FIG. 11. A GROUP OF PELVETIA, A CHARACTERISTIC HIGH-TIDE WRACK OF THE WEST COAST.

FIG. 12. THE UPPER, OR HEDOPHYLLUM ZONE, OF THE KELP FORMATION IS SHOWN IN THE FOREGROUND. IN THE MIDDLE DISTANCE ALARIA AND LAMINARIA BONGARDIANA WITH PLANTS OF EGREGIA ARE THE ABUNDANT FORMS.

Not only did they prove of unusual taxonomic interest—some entirely new species being collected—but also well worthy of careful ecological research. Their zonal distribution, formation groups and choice of special substrata were noted, together with their behavior at different stages of the tide. Often very sharp lines of demarcation between different algal societies were exhibited. In Figure 8 an excellent example is reproduced. At the rear, near the center, is seen the characteristic fringe of salal (Gaultheria shallon) in front of which Enteromorpha colonies are established upon the flat sandstone. In the foreground appears a sharp zone of wrack (Fucus evanescens). In this view there is also shown some of the unusually vigorous epiphytic moss-vegetation so

FIG. 13. IN THE FOREGROUND ARE SEEN PHYLLOSPADIX SCOULERI, LAMINARIA BONGARDIANA AND LESSONIA LITTORALIS, THE LATTER BEING A CHARACTERISTIC SURGE PLANT OF THE COAST.

abundantly represented on Vancouver island. Another very distinct instance of zonal distribution is shown in Figure 9, the photograph having been taken at low tide. In the foreground the slender leaves of a marine angiosperm (Phyllospadix scouleri) are seen, spread over which are fronds of Egregia, one of the most notable of the west coast kelps. The sides of the dome-shaped rock are draped with kelp, principally Egregia and Alaria, while the top is covered with a fairly uniform and copious growth of the alga which has passed under the name of Halosaccion hydrophora, but concerning which it is possible that an error has been made by American phycologists.

Under other topographic conditions the zonal distribution is not so

evident, and in Figure 10 is shown an arrangement of algae and animals upon a much creviced slate. Barnacles of two distinct types and mussels, mingled with a growth of Endocladia muricata, appear in this

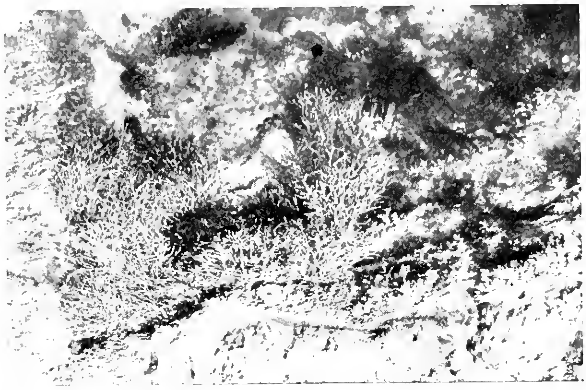


FIG. 14. CORALLINACEAE AT THE EDGE OF A TIDE-POOL, ON THE RIGHT AMPHIROA AND ON THE LEFT CORALLINA.

view, but the general grouping is less clearly concentric. Nevertheless the Endocladia zone is pretty well defined as a mid-tide algal society and sometimes shows sharp demarcation when favorably situated for a pure growth.

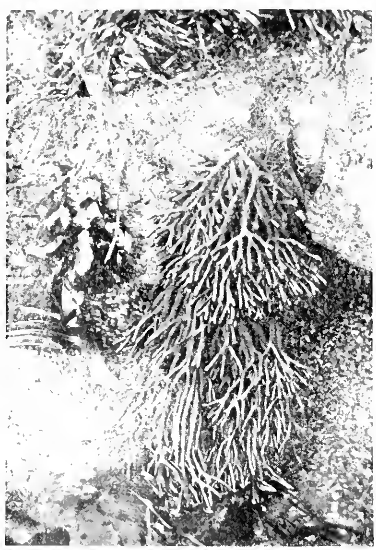


FIG. 15. A PLANT OF CODIUM MUCRONATUM CALIFORNICUM, A CHARACTERISTIC SIPHONACAEOUS ALGA OF THE TIDE-POOLS.

Among the high-tide algae—those occupying the upper zones—Pelvetia is an interesting form. It occurs at the same levels adopted by

Fucus, of which it is taxonomically an ally, and often produces considerable beds, though not everywhere abundant like the Fucus. In Figure 11 a group of Pelvetia is shown and its habit can easily be recognized.

Fig. 16. A Frond of Desmarestia ligulata herbacea taken from the Wash after a Storm.

Of the low-tide algae there is not only a characteristic segregation relative to depth of water, but a careful selection of habits more or less exposed to the influence of the surf and surge. Quite a characteristic group of surf-plants including such kelps as Postelsia palmaeformis and one species of Alaria display themselves where the surf is strongest and seem to require the foaming water of the breakers for their best development. Below these in more sheltered places one finds Hedophyllum, Alaria and Egregia. Below Postelsia, but exposed to strong surge, grow the Lessonias, while Pterygophora seeks the bottom of the surge and Nereocystis anchors itself in still deeper water outside the line of breakers. In this outer zone, too, Macrocystis and Dictyoneuron seem to find their best opportunities for growth, while Costaria comes somewhat nearer shore. The latter is, however, commonly brought up with the Nereocystis holdfasts, when they are detached from the bottom. Figure 13 shows the exposure of surge-plants at low tide. On the right is Lessonia littoralis. In front is Laminaria bongardiana and on the left is Phyllospadix scouleri. The Lessonia, in particular, is beautifully adapted by its massive trunk and slender leaves to maintain its foothold in the surge and with Postelsia in the surf and Nereocystis in the deeper water shows in magnificent fashion the work-

Fig. 17. Plant of Rhodomela floccosa taken from the Wash and Photographed in a Glass-bottomed Tank.

ing out of the same structural type under slightly different adaptational conditions.

In the sheltered pot-holes where the motion of the water *en masse* is not possible and where the total movement is comparatively less violent, one finds an altogether different flora and fauna from that in evidence on exposed reefs. Figure 14, showing the edge of a tide-pool and penetrating below the surface of the clear liquid that fills it, presents a view of two genera of Corallinaceae—Amphiroa on the right and towards the center, and Corallina on the left. Below, suffering from slight refraction, may be identified the frond of Codium mucronatum cali-

Fig. 18. Trunk of a West Coast Cedar showing the Abundant Epiphytic Vegetation and indicating the Characteristic Lomaria Formation of the Forest Floor.

fornicum. The latter alga, a somewhat characteristic inhabitant of the tide-pools, is shown exposed to the air in Figure 15. Its size may be judged by the leaves of Phyllospadix above and the Chiton clinging to the rock.

Some of the seaweeds of Port Renfrew were difficult to gather except from the wash. Here certain large forms such as Dictyoneuron, Desmarestia, Callymenia and others were particularly abundant. Figure 16

shows such a plant of Desmarestia ligulata herbacea, while Figure 17 is from a photograph made in a tank with glass bottom and shows a plant of Rhodomela floccosa.

The portraits of algae given will suffice to indicate the wealth of material awaiting study and research at the Minnesota Seaside Station. The interior country with its forest and mountains is scarcely less interesting than the shore. The botanist from the East is particularly impressed with the magnificent size of the trees, the luxuriance of the Lomaria formation of the forest-floor and the wealth of epiphytic and parasitic vegetation. The boughs of the trees are festooned with mosses

FIG. 19. MOSS-COVERED HEXENBESEN OF THE DWARF MISTLETOE ON HEMLOCK TREES NEAR PORT RENFREW.

and hepatics and their bark covered with lichens, ferns and small flowering plants. Figure 19 shows a typical colony of Polypodium scouleri upon coniferous bark and illustrates the prevalent epiphytism of ferns and mosses throughout the district. Figure 20 gives a view of mistletoe hexenbesen covered with moss and due to the action of the dwarf mistletoe, Razoumofskya pusilla. Numerous other parasitic plants are to be

found in the forest, notably Boschniakia strobilacea, a member of the broom-rape family and omnipresent upon the roots of the salal bush.

From the above it will be seen that the natural surroundings of the Minnesota Seaside Station are highly favorable for varied and productive research. The beginning that has been made has received encouragement from Canadian and American botanists, and it is possible that the modest camp on the Straits of Fuca may develop into a genuine marine laboratory with full equipment and a field of usefulness peculiarly its own. In any event it will doubtless serve as an objective point for more than one biological pilgrimage from the central-western states. During the season of 1901, when possibly the largest scientific party ever

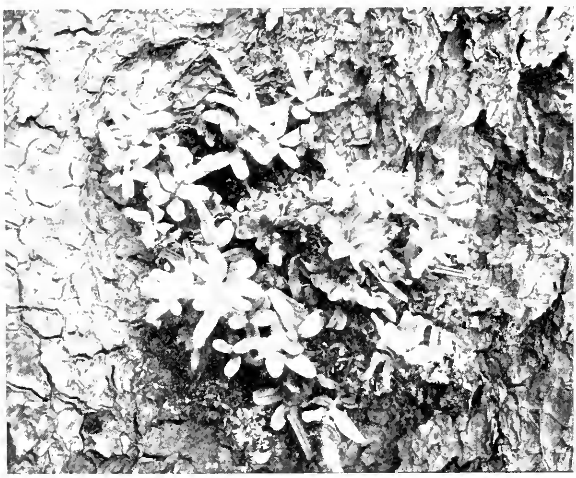


FIG. 20. POLYPODIUM SCOULERI A COMMON FERN EPIPHYTE ON TREE TRUNKS.

conducted to so distant a point was enabled to spend a pleasant and profitable six weeks in the mountains and on the shore, representatives from several universities, colleges, normal schools and high schools were in attendance, one coming all the way from Tokyo. So successful an experiment as that of the summer just past will certainly justify the organization of other parties in years to come.

The illustrations in this paper are all from photographs by C. J. Hibbard, Esq., photographer of the Department of Botany in the University of Minnesota, with the exception of Figure 6, which is from a lantern slide by Flemming Bros., of Victoria, B. C.

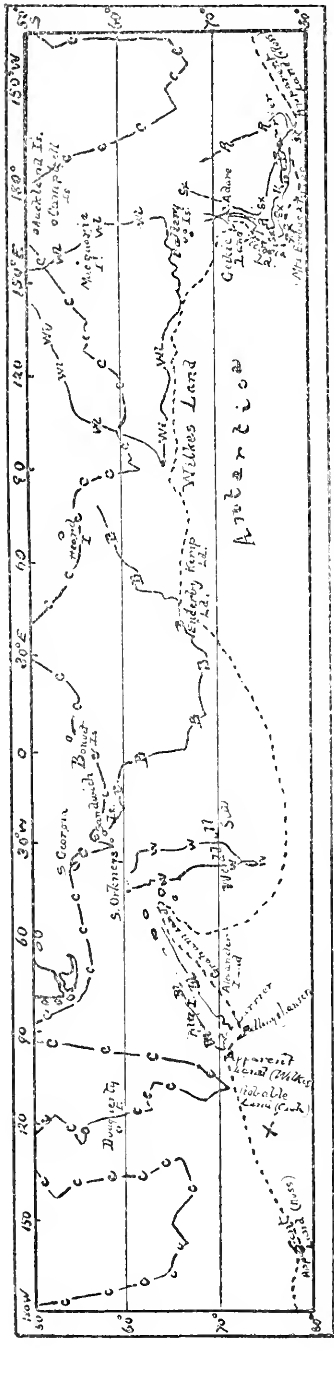
ANTARCTIC EXPLORATION.

BY PROFESSOR J. W. GREGORY, F.R.S.,
UNIVERSITY, MELBOURNE.

I. *The Search for the 'Terra Australis.'*

THE search for the supposed great southern continent roused interest in the South Polar area, even earlier than the commercial need for the Northeast or Northwest Passage directed the attention of the European nations to the Arctic seas. Long before Hudson had started the northern whale fishery, or Barents had discovered Spitzbergen, or Willoughby had set out on that 'new and strange navigation,' which, according to Milton, was intended to save England from the commercial ruin threatened by foreign competition, Arabian, Dutch and Spanish sailors had searched for a continent in the great southern sea.

Belief in the existence of this 'Terra Australis' dates from the time of the earliest classical geographies. They regarded it as a corollary of the spherical shape of the earth; for it was thought that terrestrial equilibrium could only be maintained by two land masses acting as counterpoises to the land of the old world. The existence of America was therefore predicted as the necessary western antipodes, and a great southern continent was assumed as the southern antipodes. The land that Ptolemy represented as connecting Africa and southeastern Asia and closing the Indian Ocean as a Mediterranean Sea, was regarded as part of the northern shore of this southern continent. Faith in this 'Terra Australis' has survived in spite of the repeated failures to prove its existence; for more than two and twenty centuries the supposed limits of this land have receded as geographical research advanced southward. One of the geographical results of the Indian expedition of Alexander the Great was the separation of Ceylon from the southern continent. Ptolemy's land connection between southern Africa and eastern Asia was pushed backward by the Arabian sailors who reached Australia. Confirmation of the theory was however claimed by the discovery of Terra del Fuego and Australia; but the passage of Drake's Straits and Tasman's voyage along the southern coast of Australia showed that both areas were bounded southward by the sea. Then it was asserted that New Zealand was part of the southern continent, and de Bougainville was sent in 1763 to discover colonizable parts of it, so that France might replace her lost American possessions by new settlements in the south. The French expedition, however, was disappointed



Diagrammatic Sketch Map, showing Probable Approximate Northern Coast of the Antarctic Lands and Routes of some Chief Expeditions. —C—C—Cook. —W—W—Weddell. —B—B—Biscoe. —Wl—Wl—Wilkes. —R—R—Ross in the Ross Sea. —Sx—Sx—Southern Cross. —Bl—Bl—Belgica.

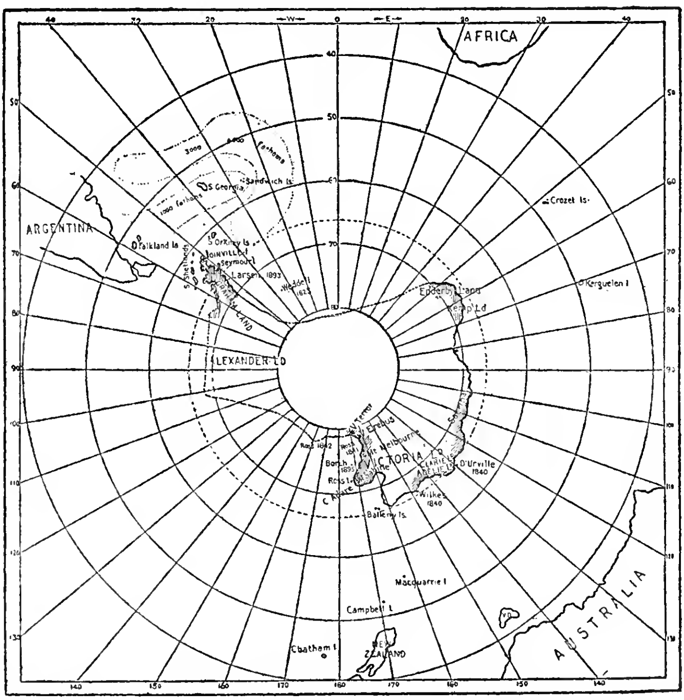
at finding only some insignificant islands, and Cook's first voyage showed that New Zealand was an independent archipelago.

In spite of the great shrinkage of the supposed southern continent caused by the expeditions of Cook and de Bougainville, there was still left an unknown area round the south pole large enough to hold a big land mass. Various new arguments were used to prove that such land must exist. De Quiros in the New Hebrides felt earthquakes traveling from the south; as it was believed that earthquakes could only originate on land, they were taken to prove the existence of a southern land.

Cook was accordingly sent on his second voyage, with orders to circumnavigate the south polar area in as high a latitude as possible. He was to search first for the land reported by Bouvet, and find if it were an island or part of a continent. If the latter he was to "explore it as much as possible, to make such notations thereon and observations as may be useful to navigation or commerce or tend to the formation of natural knowledge. He was also directed to observe the genius, temper and disposition of the inhabitants, if any, and endeavor by all proper means to cultivate their friendship and alliance, making presents and inviting them to traffic."

Cook's voyage was brilliantly successful, and still ranks as the greatest of Antarctic achieve-

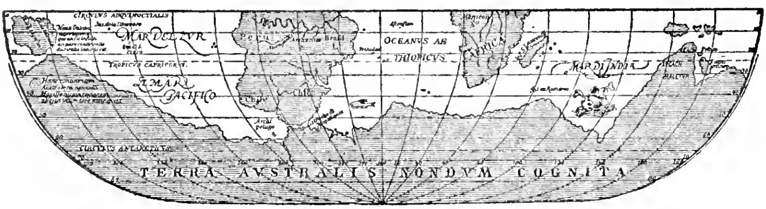
ments. He circumnavigated the south polar region, and reached latitudes which in some parts of his circuit have not yet been passed. Cook's magnificent results were all the more remarkable because of his distaste of the work. He described the sea as 'so pestered with ice,' and the lands as having 'an inexpressibly horrid aspect, and though he saw the beauty of the icebergs he regarded them with a 'mind filled with horror.' While so many coasts were uncharted and so many seas were unsurveyed Cook thought it a preposterous waste of time to hunt for a land, which, even if it existed, would be absolutely useless to his or to several succeeding generations. At times Cook was so impressed by the worthless nature of the Antarctic lands, that he believed they would be severely let alone when men heard his report of them and that they are uninhabited, uninhabitable and tradeless. If any one go further south than I have been, said Cook, 'I shall not envy him the honor of the discovery, but I will be bold to say that the world will not be benefited by it.'



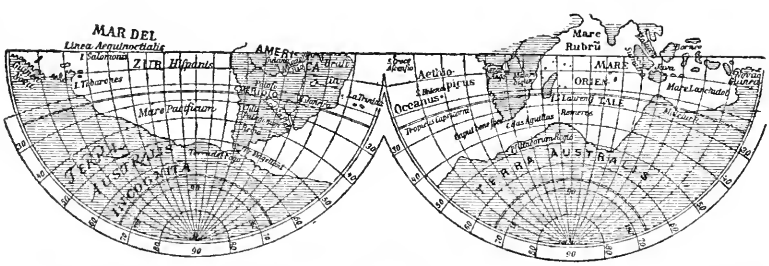
SKETCH MAP OF THE ANTARCTIC TRACT, GIVING THE MORE IMPORTANT POINTS THAT HAVE BEEN NAMED BY NAVIGATORS.

All through Cook's journal we feel his irritation at having been sent on a mission which he regarded as a waste of his time and powers. He was comforted by the thought that he had, however, finally shown

that there is no room for the Terra Australis of classical and mediaeval cartographers. Nevertheless he was convinced that there was a nucleus of land in the middle of the ice-pestered sea, for he accepted the view that thick ice is not formed on the open sea. This view was based on the argument advanced by de Brosses in 1756, that as sea ice is sweet it must be formed on land, until in 1776 Nairsie explained that ice formed by the freezing of the sea water is fresh because the salt is extruded as brine. Cook, however, was no doubt quite correct in the view that the great flat-topped Antarctic bergs could not be formed by the direct freezing of the open sea, but must have been formed on land.



TERRA AUSTRALIS (THEATRUM ORBIS TERRARUM, 1571).



TERRA AUSTRALIS, AFTER MERCATOR (ATLAS MINOR, EX-OFFICINA JOANNIS JANSSONII, 1648).

Hence in spite of the comparatively narrow limits within which Cook's work had restricted the possible existence of Antarctic land, the search for it was still continued. Islands were found south of the Atlantic; but it was not till 1840 that any extensive land area was discovered south of the Pacific and Indian Oceans. Then almost simultaneously a French expedition under Dumont d'Urville, and the American expedition under Wilkes discovered the long coast line or chain of islands known as Wilkes Land.

Wilkes' work was not only important because he traced this coast line at intervals for 60 degrees of longitude; but the geological collections made by his expedition showed that the land is formed of granites, massive sandstones and other rocks of continental types.

Two years later the extension of Wilkes Land to the east and the south was proved by the famous expedition of Sir James Clark Ross, which circumnavigated the Antarctic area and passed all previous

records by reaching the latitude of 78°. On his own lines Ross's work was magnificent. His magnetic survey has not been equalled in the Antarctic; his southern record was not passed until 1900; his discovery of Victoria Land and Mounts Erebus and Terror were geographical results of high importance. But Ross's range of interest was narrow; he did not land on the main land he discovered, and would not let his doctor, McCormick; he advanced erroneous theories of oceanic circulation, assigned wrong temperatures to the sea water, owing to misunderstanding his thermometers; he told us practically nothing of the geology of the Antarctic lands, for the few pebbles he brought back were neglected until they were recently unearthed and described by Mr. Prior.

After the voyage of Ross there was a long interval before serious work in the Antarctic was renewed. Sealers and whalers made minor geographical discoveries, and the voyage of the 'Challenger' in 1874 showed that the Antarctic sea is full of scientific interest. But it was not until 1885 and 1886 that the papers of Professor G. Neumayer, now of Hamburg, and formerly director of the Flagstaff Observatory at Melbourne, and of Sir John Murray roused fresh interest in Antarctic research. Since then the voyages of some Dundee and Norwegian sealers, of the 'Antarctic' and 'Southern Cross' in Victoria Land and the Ross Sea, and of the 'Belgica' to the south of the Atlantic have made important additions to our Antarctic knowledge.

II. *The Four Antarctic Expeditions.*

Now, in the year 1901, four expeditions are starting for the Antarctic: an English expedition under Commander R. F. Scott, R. N., in the 'Discovery,' with Mr. G. R. Murray, F.R.S., as head of the civilian scientific staff; a German expedition under Professor E. von Drygalski in the 'Gauss'; a Swedish expedition under Dr. Otto Nordenskjöld in the 'Antarctic,' and a Scotch expedition under Mr. W. S. Bruce.

The four expeditions will work as far as possible on a common plan, but in different areas. The 'Discovery' will start from New Zealand and go thence into the Ross Sea, which will be its central field of work. The German expedition will go south from Kerguelen to the western end of Wilkes Land, geographically the least known part of the Antarctic; its route will depend on the geography of the area, but the idea is to work southwestward toward the Weddell Sea, south of the Atlantic. The Swedish and Scotch expeditions both go to the South Atlantic.

The work of these expeditions will depend primarily on the geographical character of their fields of operation. The Antarctic area includes three main geographical divisions, (1) Wilkes and Victoria

Lands; (2) the division south of the Pacific from Ross's Sea to Alexander Land; (3) the Graham Land with its associated archipelagoes and the Weddell Sea that separates it from the western end of Wilkes Land.

As the first essential to the scientific investigation of a country is some acquaintance with its general topography, the primary factor in determining the work of the expeditions is the grade of our geographical knowledge of their fields of operations.

Geographical knowledge of the Antarctic is at present on two grades; in some areas the pioneer exploration has been done as far as concerns work at sea; of other areas we know nothing. Our knowledge is of the first grade in respect to only two or three areas; they are Graham Land with its associated islands and the coast of Victoria Land with the adjacent Ross Sea; perhaps we should also include in this category the northern shore of Wilkes Land, though it is known only at intervals and one of its most important areas, the angle between it and Victoria Land, is quite unknown. The rest of the Antarctic regions is on the second grade; the shores of the Weddell Sea have never been sighted; the western termination of Wilkes Land is quite hypothetical; speculations as to the area to the south of the Pacific are dependent on general considerations and the interpretation of a couple of distant and imperfectly recorded views.

Accordingly the plan of operations of each expedition should be dependent on the extent of our geographical knowledge of its field of operations. The English expedition has the advantage of a well-known entry into its central area, in which the most fruitful work will be scientific observations taken with the highest degree of accuracy and in the fullest detail. For pioneer geographical work it will be dependent on sledge expeditions inland, and at sea on how far it can push eastward from the Ross Sea into the southern Pacific.

The German expedition on the other hand goes into the region of which our ignorance is most complete. Its first work will therefore be pioneer geographical exploration, on the basis of which its expert scientific staff can found the observations that will be made concurrently. The expedition starts from the French island of Kerguelen where a base station and observatory have been established. Thence the 'Gauss' will sail due southward toward the supposed western end of Wilkes Land, and enter the ice near Enderby Land. Thenceforth its progress will depend on the character of that region. The general idea is to work slowly southwestward into the Weddell Sea, sending out sledge expeditions to explore any lands that may be seen. The proposed route of the ship has the drawback that it may be contrary to the prevalent drift of the ice and currents. Accordingly the expedition has been equipped on the expectation of a long, slow battle

with the ice. The 'Gauss' has been designed for strength, not speed, and has been fitted up so as to make the minimum possible demands on its coal consumption for steaming, scientific work and domestic use. The number of the staff has been kept lower than on the English expedition so that the food supply may be larger and last longer. To make up for the smallness of the crew, 70 dogs have been provided for sledge expeditions. Further various tempting fields of scientific work are to be left unentered as impracticable with the available cargo capacity of the ship.

The Swedish and Scotch expeditions both go to an area where the opportunity for work largely depends on the particular ice conditions of the season. If the ice be open and the Weddell Sea fairly clear, they may reach high latitudes and discover the southern boundary of the South Atlantic basin. As so much depends on the chances of the weather, the plan in both cases is to establish stations on shore as far south as possible, and for the ships to leave the ice at the end of the summer and undertake oceanographic research outside the ice pack during the winter.

III. *The Problems of the Antarctic.*

The frequency of enquiries as to the practical value of Antarctic research shows that popular interest in the subject still values results from what it chooses to call their 'usefulness.' Information as to the meteorology and magnetic phenomena of the Antarctic regions may prove of value in navigation and weather prediction. Unexpected stores of economic products may be found on land or at sea. Nevertheless it must be admitted that the hope of practical rewards is a less powerful incentive to Antarctic exploration than the desire for new facts of theoretical value. The expeditions seek knowledge because it is knowledge rather than because it may be power. The first problem which the collated reports of the four expeditions will be expected to answer is whether the hypothetical 'Terra Australis' has any existence at the present day. Opinions are divided on this question. According to one school the Antarctic lands mostly belong to a great south polar continent; according to another there is no continent but only a number of comparatively small and widely scattered islands. Sir John Murray is the leading champion of the continental hypothesis; he has sketched the probable outline of his 'Antarctica' and represents it as an irregularly triangular area, of a size fully entitling it to rank as a continent.

That the Antarctic lands belong to a continent *geologically* there can be no doubt; for rocks of a typical continental character have now been collected from most of them, including Victoria Land, Wilkes Land and Graham Land. Specimens are now especially wanted

from Dougherty Island and Peter Island in the southern Pacific. Meteorological evidence supports the idea that the Antarctic is still a continent *geographically,* and that the center of the land is not coincident with the south pole, but is in the eastern part of the area.

The available evidence appears to be decidedly in favor of Sir John Murray's theory, though the question cannot be definitely settled until the range of the land has been mapped. This task may be facilitated by the guidance as to the probable trend and position of the coasts, that is given by the principles of geomorphology.

If the current theory of the structural unity of the Pacific ocean be correct, then that ocean must be bounded on the south by a coast of the 'Pacific type.' With one exception in Central America the whole of the known coasts of the Pacific belong to what Suess has called the 'Pacific type.' The main character of this form of coast is that the trend is determined by mountain ranges running parallel to the shore. In the South Pacific this type is well exemplified by New Zealand on one side and by the Andes of South America on the other. In southern Patagonia the Andes are turned from their meridional course and run eastward across Terra del Fuego. The tectonic line of the Andes is then apparently bent suddenly southward and reappears in Graham Land. It is probably continued round the southern Pacific, meeting the known end of the New Zealand line near Mounts Erebus and Terror.

The theory of the structural unity of the Pacific is sufficiently established to render it probable that Cook was close to land when he turned back from his furthest south in the South Pacific (71°S. 122°E.), that the 'ice-barriers' of Ross and Bellingshausen are both the fronts of glaciers flowing from highlands to the south; that there is a land connection of the Pacific coast type running from Ross's ice barriers northeastward to Graham Land; and that Victoria Land is connected to Wilkes Land by a broad bight.

There are no such data for predictions as to the distribution of land and water in the German and Scotch areas of work. For Wilkes Land and the lands that may extend thence westward towards Graham Land are no doubt plateau countries bounded to the north by coasts of the 'Atlantic type'; and the trend of such coasts is not determined by simple continuous tectonic lines. That Wilkes Land and Geikie Land repeat the structure of southern Australia is rendered probable by the geological collections of all the expeditions from Wilkes to the 'Southern Cross.' The westward extension of this land line has probably the same structure, and it is accordingly impossible to predict how far the Weddell cuts into the Antarctic lands.

The principles of geomorphology not only suggest the external shape of 'Antarctica' but also its internal relief. It is probable that it

is not a dome of land increasing in height slowly from the coasts to a central point near the South Pole; it is more likely to consist of a lofty mountain range running near the Pacific shore and of a broad plateau sloping downward from this mountain axis across the pole to Weddell Sea on the one side and the bight between Wilkes Land and Enderby Land on the other.

The remaining problems of the Antarctic are of less general and more technical interest. The magnetic survey, the need for which led to the British Government's contribution of £45,000 to the cost of the 'Discovery,' is generally regarded as the most important item in the scientific program. The principal point to be determined by the British expedition is the variation in the magnetic elements since the surveys of Ross and of Clerk and Moore. The deep fauna of the Antarctic seas was proved by the 'Challenger' and the 'Belgica' to be rich in new forms of life; and according to Murray the Antarctic and Arctic faunas have many elements in common. More material is needed for the proper analysis of the resemblances between the two faunas, and the collections may be expected to yield some hitherto undiscovered animals of ancient types.

The exact shape of the earth is another question which cannot be settled without fresh evidence from the Antarctic. For this purpose two at least of the expeditions have been provided with pendulum outfits; by noting the exact length of time occupied by the swing of a pendulum the distance of the place of observation from the earth's center can be determined. It is held that the south polar region projects further from the plane of the equator than does the north polar region; according to one estimate the south pole is slightly more than one hundredth further from the earth's center than the north pole.

The work of the expeditions includes researches in the physics of glacier ice, a subject in which Professor von Drygalski is an expert, on the distribution and spectroscopic phenomena of the Aurora; on the composition and movements of the atmosphere, and the currents of the Antarctic Seas.

If the explorers only have the success which they deserve their arduous and devoted labors will contribute materially toward the progress of many branches of science. In fact, as Sir John Murray assures us, 'the results of a successful Antarctic expedition would mark a great advance in the philosophy—apart from the mere facts—of terrestrial science.'

THE POSSIBLE IMPROVEMENT OF THE HUMAN BREED UNDER THE EXISTING CONDITIONS OF LAW AND SENTIMENT.*

By FRANCIS GALTON, D.C.L., D.Sc., F.R.S.,
LONDON.

IN fulfilling the honorable charge that has been entrusted to me of delivering the Huxley lecture, I shall endeavor to carry out what I understand to have been the wish of its founders, namely, to treat broadly some new topic belonging to a class in which Huxley himself would have felt a keen interest, rather than to expatiate on his character and the work of his noble life.

That which I have selected for to-night is one which has occupied my thoughts for many years, and to which a large part of my published inquiries have borne a direct though silent reference. Indeed, the remarks I am about to make would serve as an additional chapter to my books on 'Hereditary Genius' and on 'Natural Inheritance.' My subject will be the possible improvement of the human race under the existing conditions of law and sentiment. It has not hitherto been approached along the ways that recent knowledge has laid open, and it occupies in consequence a less dignified position in scientific estimation than it might. It is smiled at as most desirable in itself and possibly worthy of academic discussion, but absolutely out of the question as a practical problem. My aim in this lecture is to show cause for a different opinion. Indeed I hope to induce anthropologists to regard human improvement as a subject that should be kept openly and squarely in view, not only on account of its transcendent importance, but also because it affords excellent but neglected fields for investigation. I shall show that our knowledge is already sufficient to justify the pursuit of this, perhaps the grandest of all objects, but that we know less of the conditions upon which success depends than we might and ought to ascertain. The limits of our knowledge and of our ignorance will become clearer as we proceed.

Human Variety.

The natural character and faculties of human beings differ at least as widely as those of the domesticated animals, such as dogs and horses, with whom we are familiar. In disposition some are gentle and good-

* The second Huxley Lecture of the Anthropological Institute, delivered on October 29, 1901.

tempered, others surly and vicious; some are courageous, others timid; some are eager, others sluggish; some have large powers of endurance, others are quickly fatigued; some are muscular and powerful, others are weak; some are intelligent, others stupid; some have tenacious memories of places and persons, others frequently stray and are slow at recognizing. The number and variety of aptitudes, especially in dogs, is truly remarkable; among the most notable being the tendency to herd sheep, to point and to retrieve. So it is with the various natural qualities that go towards the making of civic worth in man. Whether it be in character, disposition, energy, intellect or physical power, we each receive at our birth a definite endowment, allegorized by the parable related in St. Matthew, some receiving many talents, others few; but each person being responsible for the profitable use of that which has been entrusted to him.

Distribution of Qualities in a Nation.

Experience shows that while talents are distributed in endless different degrees, the frequency of those different degrees follows certain statistical laws, of which the best known is the Normal Law of Frequency. This is the result whenever variations are due to the combined action of many small and different causes, whatever may be the causes and whatever the object in which the variations occur, just as twice 2 always makes 4, whatever the objects may be. It therefore holds true with approximate precision for variables of totally different sorts, as, for instance, stature of man, errors made by astronomers in judging minute intervals of time, bullet marks around the bull's-eye in target practice, and differences of marks gained by candidates at competitive examinations. There is no mystery about the fundamental principles of this abstract law; it rests on such simple fundamental conceptions as, that if we toss two pence in the air they will, in the long run, come down one head and one tail twice as often as both heads or both tails. I will assume then, that the talents, so to speak, that go to the formation of civic worth are distributed with rough approximation according to this familiar law. In doing so, I in no way disregard the admirable work of Professor Karl Pearson on the distribution of qualities, for which he was adjudged the Darwin Medal of the Royal Society a few years ago. He has amply proved that we must not blindly trust the Normal Law of Frequency; in fact, that when variations are minutely studied they rarely fall into that perfect symmetry about the mean value which is one of its consequences. Nevertheless, my conscience is clear in using this law in the way I am about to. I say that *if* certain qualities vary normally, such and such will be the results; that these qualities are of a class that are found, whenever they have been tested, to vary

normally to a fair degree of approximation, and consequently we may infer that our results are trustworthy indications of real facts.

A talent is a sum whose exact value few of us care to know, although we all appreciate the inner sense of the beautiful parable. I will, therefore, venture to adapt the phraseology of the allegory to my present purpose by substituting for 'talent' the words 'normal-talent.' The value of this normal-talent in respect to each and any specified quality or faculty is such that one-quarter of the people receive for their respective shares more than one normal-talent *over and above* the average of all the shares. Our normal-talent is therefore identical with what is technically known as the 'probable error.' Therefrom the whole of the following table starts into life, evolved from that of the '*probability integral.*' It expresses the distribution of any normal

TABLE I.—*Normal Distribution (to the nearest per ten thousand and to the nearest per hundred).*

—4° —3° —2° —1° M +1° +2° +3° +4°

v and below	*u*	*t*	*s*	*r*	R	S	T	U	V and above.	Total
35	180	672	1613	2500	2500	1613	672	180	35	10,000
2		7	16	25	25	16	7	2		100

quality, or any group of normal qualities, among 10,000 persons in terms of the normal-talent. The M in the upper line occupies the position of Mediocrity, or that of the average of what all have received: the +1°, +2°, etc., and the —1°, —2°, etc., refer to normal talents. These numerals stand as graduations at the heads of the vertical lines by which the table is divided. The entries between the divisons are the numbers per 10,000 of those who receive sums between the amounts specified by those divisions. Thus, by the hypothesis, 2,500 receive more than M but less than M+1°, 1,613 receive more than M+1° but less than M+2°, and so on. The terminals have only an inner limit, thus 35 receive more than 4°, some to perhaps a very large but indefinite amount. The divisions might have been carried much farther, but the numbers in the classes between them would become less and less trustworthy. The left half of the series exactly reflects the right half. As it will be useful henceforth to distinguish these classes, I have used the *capital* or large letters, R, S, T, U, V, for those above mediocrity and corresponding *italic* or small letters, *r, s, t, u, v,* for those below mediocrity, *r* being the counterpart of R, *s* of S, and so on.

In the lowest line the same values are given, but more roughly, to the nearest whole percentage.

It will assist in comprehending the values of different grades of

civic worth to compare them with the corresponding grades of adult male stature in our nation. I will take the figures from my 'Natural Inheritance,' premising that the distribution of stature in various peoples has been well investigated and shown to be closely normal. The average height of the adult males, to whom my figures refer, was nearly 5 feet 8 inches, and the value of their 'normal-talent' (which is a measure of the spread of distribution) was very nearly 1¾ inches. From these data it is easily reckoned that Class U would contain men whose heights exceed 6 feet 1¼ inches. Even they are tall enough to overlook a hatless mob, while the higher classes, such as V, W and X, tower above it in an increasingly marked degree. So the civic worth (however that term may be defined) of U-class men, and still more of V-class, are notably superior to the crowd, though they are far below the heroic order. The rarity of a V-class man in each specified quality or group of qualities is as 35 in 10,000, or say, for the convenience of using round numbers, as 1 to 300. A man of the W class is ten times rarer, and of the X class rarer still; but I shall avoid giving any more exact definition of X than as a value considerably rarer than V. This gives a general but just idea of the distribution throughout a population of each and every quality taken separately so far as it is normally distributed. As already mentioned, it does the same for *any* group of normal qualities; thus, if marks for classics and for mathematics were severally normal in their distribution, the combined marks gained by each candidate in both those subjects would be distributed normally also, this being one of the many interesting properties of the law of frequency.

Comparison of the Normal Classes with those of Mr. Booth.

Let us now compare the normal classes with those into which Mr. Charles Booth has divided the population of all London, in a way that corresponds not unfairly with the ordinary conception of grades of civic worth. He reckons them from the lowest upwards, and gives the numbers in each class for East London. Afterwards he treats all London in a similar manner, except that sometimes he combines two classes into one and gives the joint result. For my present purpose, I had to couple them somewhat differently, first disentangling them as I best could. There seemed no better way of doing this than by assigning to the members of each couplet the same proportions that they had in East London. Though this was certainly not accurate, it is probably not far wrong. Mr. Booth has taken unheard-of pains in this great work of his to arrive at accurate results, but he emphatically says that his classes cannot be separated sharply from one another. On the contrary, their frontiers blend, and this justifies me in taking slight liberties with his figures. His class A consists of criminals, semi-

criminals, loafers and some others, who are in number at the rate of 1 per cent. in all London—that is 100 per 10,000, or nearly three times as many as the *v* class: they therefore include the whole of *v* and spread upwards into the *u*. His class B consists of very poor persons who subsist on casual earnings, many of whom are inevitably poor from shiftlessness, idleness or drink. The numbers in this and the A class combined closely correspond with those in *t* and all below *t*.

Class C are supported by intermittent earnings; they are a hard-working people, but have a very bad character for improvidence and shiftlessness. In Class D the earnings are regular, but at the low rate of twenty-one shillings or less a week, so none of them rise above poverty, though none are very poor. D and C together correspond to the whole of *s* combined with the lower fifth of *r*. The next class, E, is the largest of any, and comprises all those with regular standard earnings of twenty-two to thirty shillings a week. This class is the recognized field for all forms of cooperation and combination; in short for trades unions. It corresponds to the upper four fifths of *r* and the lower four-fifths of R. It is therefore essentially the mediocre class, standing as far below the highest in civic worth as it stands above the lowest class with its criminals and semi-criminals. Next above this large mass of mediocrity comes the honorable class *F*, which consists of better paid artisans and foremen. These are able to provide adequately for old age, and their sons become clerks and so forth. *G* is the lower middle class of shop-keepers, small employers, clerks and subordinate professional men, who as a rule are hard-working, energetic and sober. F and G combined correspond to the upper fifth of R and the whole of S, and are, therefore, a counterpart to D and C. All above G are put together by Mr. Booth into one class H, which corresponds to our T, U, V and above, and is the counterpart of his two lowermost classes, A and B. So far, then, as these figures go, civic worth is distributed in fair approximation to the normal law of frequency. We also see that the classes *t, u, v* and below are undesirables.

Worth of Children.

The brains of the nation lie in the higher of our classes. If such people as would be classed W or X could be distinguishable as children and procurable by money in order to be reared as Englishmen, it would be a cheap bargain for the nation to buy them at the rate of many hundred or some thousands of pounds per head. Dr. Farr, the eminent statistician, endeavored to estimate the money worth of an average baby born to the wife of an Essex laborer and thenceforward living during the usual time and in the ordinary way of his class. Dr. Farr, with accomplished actuarial skill, capitalized the value at the child's birth of two classes of events, the one the cost of maintenance while a

child and when helpless through old age, the other its earnings as boy and man. On balancing the two sides of the account the value of the baby was found to be five pounds. On a similar principle, the worth of an X-class baby would be reckoned in thousands of pounds. Some such 'talented' folk fail, but most succeed, and many succeed greatly. They found great industries, establish vast undertakings, increase the wealth of multitudes and amass large fortunes for themselves. Others, whether they be rich or poor, are the guides and light of the nation, raising its tone, enlightening its difficulties and imposing its ideals. The great gain that England received through the immigration of the Huguenots would be insignificant to what she would derive from an annual addition of a few hundred children of the classes W and X. I have tried, but not yet succeeded to my satisfaction, to make an approximate estimate of the worth of a child at birth according to the class he is destined to occupy when adult. It is an eminently important subject for future investigators, for the amount of care and cost that might profitably be expended in improving the race clearly depends on its result.

Descent of Qualities in a Population.

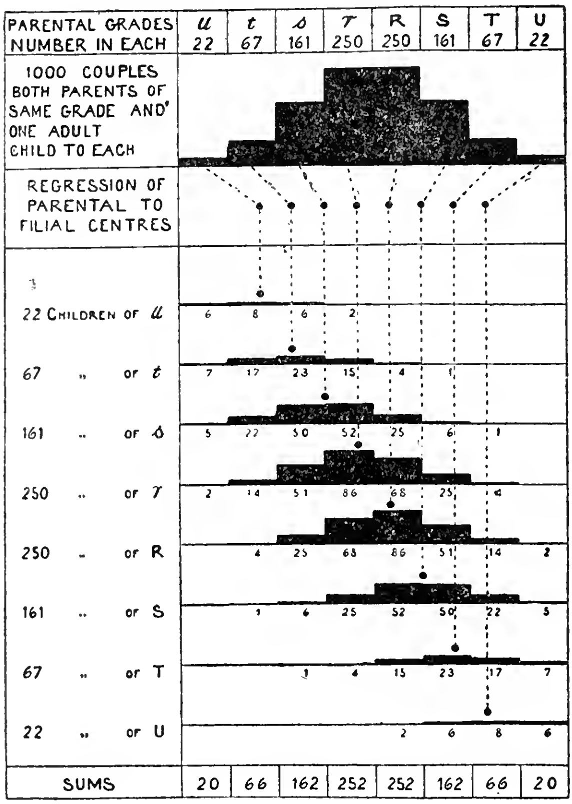
Let us now endeavor to obtain a correct understanding of the way in which the varying qualities of each generation are derived from those of its predecessor. How many, for example, of the V class in the offspring come respectively from the V, U, T, S and other classes of parentage? The means of calculating this question for a normal population are given fully in my 'Natural Inheritance.' There are three main senses in which the word parentage might be used. They differ widely, so the calculations must be modified accordingly. (1) The amount of the quality or faculty in question may be known in each parent. (2) It may be known in only one parent. (3) The two parents may belong to the same class, a V-class father in the scale of male classification always marrying a V-class mother, occupying identically the same position in the scale of female classification.

I select this last case to work out as being the one with which we shall here be chiefly concerned. It has the further merit of escaping some tedious preliminary details about converting female faculties into their corresponding male equivalents, before men and women can be treated statistically on equal terms. I shall assume in what follows that we are dealing with an ideal population, in which all marriages are equally fertile, and which is statistically the same in successive generations both in numbers and in qualities, so many per cent. being always this, so many always that, and so on. Further, I shall take no notice of offspring who die before they reach the age of marriage, nor shall I regard the slight numerical inequality of the sexes, but will

simply suppose that each parentage produces one couplet of grown-up filials, an adult man and an adult woman.

The result is shown to the nearest whole per thousand in the diagram up to 'U and above.' It may be read either as applying to fathers and their sons when adult, or to mothers and their daughters when adult, or, again, to parentages and filial couplets. I will not now attempt to explain the details of the calculation to those to whom these methods

STANDARD SCHEME OF DESCENT



are new. Those who are familiar with them will easily understand the exact process from what follows. There are three points of reference in a scheme of descent which may be respectively named 'mid-parental,' 'genetic' and 'filial' centers. In the present case of both parents being alike, the position of the mid-parental center is identical with that of either parent separately. The position of the filial center is that from which the children disperse. The genetic center occupies the same position in the parental series that the filial center does in the filial series. 'Natural Inheritance' contains abundant proof, both observational and

theoretical, that the genetic center is not and cannot be identical with the parental center, but is always more mediocre, owing to the combination of ancestral influences—which are generally mediocre—with the purely parental ones. It also shows that the regression from the parental to the genetic center, in the case of stature at least, would amount to two thirds under the conditions we are now supposing. The regression is indicated in the diagram by converging lines which are directed towards the same point below, but are stopped at one third of the distance on the way to it. The contents of each parental class are supposed to be concentrated at the foot of the median axis of that class, this being the vertical line that divides its contents into equal parts. Its position is approximately, but not exactly, half-way between the divisions that bound it, and is as easily calculated for the extreme classes, which have no outer terminals, as for any of the others. These median points are respectively taken to be the positions of the parental centers of the whole of each of the classes; therefore the positions attained by the converging lines that proceed from them at the points where they are stopped, represent the genetic centers. From these the filials disperse to the right and left with a 'spread' that can be shown to be three quarters that of the parentages. Calculation easily determines the number of the filials that fall into the class in which the filial center is situated, and of those that spread into the classes on each side. When the parental contributions from all the classes to each filial class are added together they will express the distribution of the quality among the whole of the offspring. Now it will be observed in the table that the numbers in the classes of the offspring are identical with those of the parents, when they are reckoned to the nearest whole percentage, as should be the case according to the hypothesis. Had the classes been narrower and more numerous, and if the calculations had been carried on to two more places of decimals, the correspondence would have been identical to the nearest ten thousandth. It was unnecessary to take the trouble of doing this, as the table affords a sufficient basis for what I am about to say. Though it does not profess to be more than approximately true in detail, it is certainly trustworthy in its general form, including as it does the effects of regression, filial dispersion, and the equation that connects a parental generation with a filial one when they are statistically alike. Minor corrections will be hereafter required, and can be applied when we have a better knowledge of the material. In the meantime it will serve as a standard table of descent from each generation of a people to its successor.

Economy of Effort.

I shall now use the table to show the economy of concentrating our attention upon the highest classes. We will therefore trace the origin

of the V class—which is the highest in the table. Of its 34 or 35 sons, 6 come from V parentages, 10 from U, 10 from T, 5 from S, 3 from R, and none from any class below R. But the numbers of the contributing parentages have also to be taken into account. When this is done, we see that the lower classes make their scores owing to their quantity and not to their quality; for while 35 V-class parents suffice to produce 6 sons of the V class, it takes 2,500 R-class fathers to produce 3 of them. Consequently the richness in produce of V-class parentages is to that of the R-class in an inverse ratio, or as 143 to 1. Similarly, the richness in produce of V-class children from parentages of the classes U, T, S, respectively, is as 3, 11½ and 55, to 1. Moreover, nearly one-half of the produce of V-class parentages are V or U taken together, and nearly three quarters of them are either V, U or T. If then we desire to increase the output of V-class offspring, by far the most profitable parents to work upon would be those of the V class, and in a threefold less degree those of the U class.

When both parents are of the V class the quality of parentages is greatly superior to those in which only one parent is a V. In that case the regression of the genetic center goes twice as far back towards mediocrity, and the spread of the distribution among filials becomes nine tenths of that among the parents, instead of being only three-quarters. The effect is shown in Table II.

TABLE II.—*Distribution of Sons. (I) One parent of class V., the other unknown. (2) Both parents of class V (from Table II., with decimal point and an o).*

	Distribution of Sons								Total
	t	*s*	*r*	R	S	T	U	V	
One V-parent	0.3	1.2	3.5	7.9	9.6	7.5	3.6	1.3	34.3
Two V-parents				3.0	5.0	10.0	10.0	6.0	34.0

Position of the filial center of (1) = 1.44, of (2) = 2.89. When both parents are T it = 1.58.

There is a difference of fully two divisions in the position of the genetic center, that of the single V parentage being only a trifle nearer mediocrity than that of the double T. Hence it would be bad economy to spend much effort in furthering marriages with a high class on only one side.

Marriage of Like to Like.

In each class of society there is a strong tendency to intermarriage, which produces a marked effect in the richness of brain power of the more cultured families. It produces a still more marked effect of another kind at the lowest step of the social scale, as will be painfully evident from the following extracts from the work of Mr. C. Booth

(i. 38), which refer to his Class A, who form, as has been said, the lowermost third of our '*v* and below.' "Their life is the life of savages, with vicissitudes of extreme hardship and occasional excess. From them come the battered figures who slouch through the streets and play the beggar or the bully. They render no useful service, they create no wealth, more often they destroy it. They degrade whatever they touch, and as individuals are perhaps incapable of improvement . . . but I do not mean to say that there are not individuals of every sort to be found in the mass. Those who are able to wash the mud may find some gems in it. There are at any rate many very piteous cases. Whatever doubt there may be as to the exact numbers of this class, it is certain that they bear a very small proportion to the rest of the population, or even to Class B, with which they are mixed up and from which it is at times difficult to separate them. . . . They are barbarians, but they are a handful. . . ." He says further, "It is much to be desired and to be hoped that this class may become less hereditary in its character; there appears to be no doubt that it is now hereditary to a very considerable extent."

Many who are familiar with the habits of these people do not hesitate to say that it would be an economy and a great benefit to the country if all habitual criminals were resolutely segregated under merciful surveillance and peremptorily denied opportunities for producing offspring. It would abolish a source of suffering and misery to a future generation, and would cause no unwarrantable hardship in this.

Diplomas.

It will be remembered that Mr. Booth's classification did not help us beyond classes higher than S in civic worth. If a strong and widely felt desire should arise, to discover young men whose position was of the V, W or X order, there would not be much difficulty in doing so. Let us imagine, for a moment, what might be done in any great university, where the students are in continual competition in studies, in athletics, or in public meetings, and where their characters are publicly known to associates and to tutors. Before attempting to make a selection, acceptable definitions of civic worth would have to be made in alternative terms, for there are many forms of civic worth. The number of men of the V, W or X classes whom the university was qualified to contribute annually must also be ascertained. As was said, the proportion in the general population of the V class to the remainder is as 1 to 300, and that of the W class as 1 in 3,000. But students are a somewhat selected body because the cleverest youths, in a scholastic sense, usually find their way to universities. A considerably high level, both intellectually and physically, would be required as a qualification for candidature. The limited number who had not been auto-

matically weeded away by this condition might be submitted in some appropriate way to the independent votes of fellow-students on the one hand, and of tutors on the other, whose ideals of character and merit necessarily differ. This ordeal would reduce the possible winners to a very small number, out of which an independent committee might be trusted to make the ultimate selection. They would be guided by personal interviews. They would take into consideration all favorable points in the family histories of the candidates, giving appropriate hereditary weight to each. Probably they would agree to pass over unfavorable points, unless they were notorious and flagrant, owing to the great difficulty of ascertaining the real truth about them. Ample experience in making selections has been acquired even by scientific societies, most of which work well, including perhaps the award of their medals, which the fortunate recipients at least are tempted to consider judicious. The opportunities for selecting women in this way are unfortunately fewer, owing to the smaller number of female students between whom comparisons might be made on equal terms. In the selection of women, when nothing is known of their athletic proficiency, it would be especially necessary to pass a high and careful medical examination; and as their personal qualities do not usually admit of being tested so thoroughly as those of men, it would be necessary to lay all the more stress on hereditary family qualities, including those of fertility and prepotency.

Correlation between Promise in Youth and subsequent Performance.

No serious difficulty seems to stand in the way of classifying and giving satisfactory diplomas to youths of either sex, supposing there were a strong demand for it. But some real difficulty does lie in the question—Would such a classification be a trustworthy forecast of qualities in later life? The scheme of descent of qualities may hold good between the parents and the offspring at similar ages, but that is not the information we really want. It is the descent of qualities from men to men, not from youths to youths. The accidents that make or mar a career do not enter into the scope of this difficulty. It resides entirely in the fact that the development does not cease at the time of youth, especially in the higher natures, but that faculties and capabilities which were then latent subsequently unfold and become prominent. Putting aside the effects of serious illness, I do not suppose there is any risk of retrogression in capacity before old age comes on. The mental powers that a youth possesses continue with him as a man; but other faculties and new dispositions may arise and alter the balance of his character. He may cease to be efficient in the way of which he gave promise, and he may perhaps become efficient in unexpected directions.

The correlation between youthful promise and performance in mature life has never been properly investigated. Its measurement presents no greater difficulty, so far as I can foresee, than in other problems which have been successfully attacked. It is one of those alluded to in the beginning of this lecture as bearing on race-improvement, and being on its own merits suitable for anthropological inquiry. Let me add that I think its neglect by the vast army of highly educated persons who are connected with the present huge system of competitive examinations to be gross and unpardonable. Neither schoolmasters, tutors, officials of the universities, nor of the State department of education, have ever to my knowledge taken any serious step to solve this important problem, though the value of the present elaborate system of examinations cannot be rightly estimated until it is solved. When the value of the correlation between youthful promise and adult performance shall have been determined, the figures given in the table of descent will have to be reconsidered.

Augmentation of Favored Stock.

The possibility of improving the race of a nation depends on the power of increasing the productivity of the best stock. This is far more important than that of repressing the productivity of the worst. They both raise the average, the latter by reducing the undesirables, the former by increasing those who will become the lights of the nation. It is therefore all important to prove that favor to selected individuals might so increase their productivity as to warrant the expenditure in money and care that would be necessitated. An enthusiasm to improve the race would probably express itself by granting diplomas to a select class of young men and women, by encouraging their intermarriages, by hastening the time of marriage of women of that high class, and by provision for rearing children healthily. The means that might be employed to compass these ends are dowries, especially for those to whom moderate sums are important, assured help in emergencies during the early years of married life, healthy homes, the pressure of public opinion, honors, and above all the introduction of motives of religious or quasi-religious character. Indeed, an enthusiasm to improve the race is so noble in its aim that it might well give rise to the sense of a religious obligation. In other lands there are abundant instances in which religious motives make early marriages a matter of custom, and continued celibacy to be regarded as a disgrace, if not a crime. The customs of the Hindoos, also of the Jews, especially in ancient times, bear this out. In all costly civilizations there is a tendency to shrink from marriage on prudential grounds. It would, however, be possible so to alter the conditions of life that the most prudent course for an X class person should lie exactly opposite to its present direction, for

he or she might find that there were advantages and not disadvantages in early marriage, and that the most prudent course was to follow their natural instincts.

We have now to consider the probable gain in the number and worth of adult offspring to these favored couples. First as regards the effect of reducing the age at marriage. There is unquestionably a tendency among cultured women to delay or even to abstain from marriage; they dislike the sacrifice of freedom and leisure, of opportunities for study and of cultured companionship. This has to be reckoned with. I heard of the reply of a lady official of a College for Women to a visitor who inquired as to the after life of the students. She answered that one third profited by it, another third gained little good, and a third were failures. 'But what becomes of the failures?' 'Oh, they marry.'

There appears to be a considerable difference between the earliest age at which it is physiologically desirable that a woman should marry and that at which the ablest, or at least the most cultured, women usually do. Acceleration in the time of marriage, often amounting to 7 years, as from 28 or 29 to 21 or 22, under influences such as those mentioned above, is by no means improbable. What would be its effect on productivity? It might be expected to act in two ways:

(1) By shortening each generation by an amount roughly proportionate to the diminution in age at which marriage occurs. Suppose the span of each generation to be shortened by one sixth, so that six take the place of five, and that the productivity of each marriage is unaltered, it follows that one sixth more children will be brought into the world during the same time, which is, roughly, equivalent to increasing the productivity of an unshortened generation by that amount.

(2) By saving from certain barrenness the earlier part of the child-bearing period of the woman. Authorities differ so much as to the direct gain of fertility due to early marriage that it is dangerous to express an opinion. The large and thriving families that I have known were the offspring of mothers who married very young.

The next influence to be considered is that of healthy homes. These and a simple life certainly conduce to fertility. They also act indirectly by preserving lives that would otherwise fail to reach adult age. It is not necessarily the weakest who perish in this way, for instance, zymotic disease falls indiscriminately on the weak and the strong.

Again, the children would be healthier and therefore more likely in their turn to become parents of a healthy stock. The great danger to high civilizations, and remarkably so to our own, is the exhaustive drain upon the rural districts to supply large towns. Those who come up to the towns may produce large families, but there is much reason to

believe that these dwindle away in subsequent generations. In short, the towns sterilize rural vigor.

As one of the reasons for choosing the selected class would be that of hereditary fertility, it follows that the selected class would respond more than other classes to the above influences.

I do not attempt to appraise the strength of the combined six influences just described. If each added one sixth to the produce the number of offspring would be doubled. This does not seem impossible considering the large families of colonists, and of those in many rural districts; but it is a high estimate. Perhaps the fairest approximation may be that these influences would cause the X women to bring into the world an average of one adult son and one adult daughter *in addition* to what they would otherwise have produced. The table of descent applies to one son or to one daughter per couple; it may now be read as specifying the net gain and showing its distribution. Should this estimate be thought too high, the results may be diminished accordingly.

It is no absurd idea that outside influences should hasten the age of marrying and make it customary for the best to marry the best. A superficial objection is sure to be urged that the fancies of young people are so incalculable and so irresistible that they cannot be guided. No doubt they are so in some exceptional cases. I lately heard from a lady who belonged to a county family of position that a great aunt of hers had scandalized her own domestic circle two generations ago by falling in love with the undertaker at her father's funeral and insisting on marrying him. Strange vagaries occur, but considerations of social position and of fortune, with frequent opportunities of intercourse, tell much more in the long run than sudden fancies that want roots. In a community deeply impressed with the desire of encouraging marriages between persons of equally high ability, the social pressure directed to produce the desired end would be so great as to ensure a notable amount of success.

Profit and Loss.

The problem to be solved now assumes a clear shape. A child of the X class (whatever X signifies) would have been worth so and so at its birth, and one of each of the other grades respectively would have been worth so and so; 100 X parentages can be made to produce a net gain of 100 adult sons and 100 adult daughters who will be distributed among the classes according to the standard table of descent. The total value of the prospective produce of the 100 parentages can then be estimated by an actuary, and consequently the sum that it is legitimate to spend in favoring an X parentage. The clear and distinct statement of a problem is often more than half way towards its solution. There seems no reason why this one should not be solved between limiting values that are not too wide apart to be useful.

Existing Activities.

Leaving aside profitable expenditure from a purely money point of view, the existence should be borne in mind of immense voluntary activities that have nobler aims. The annual voluntary contributions in the British Isles to public charities alone amount, on the lowest computation, to fourteen million pounds, a sum which Sir H. Burdett asserts on good grounds is by no means the maximum obtainable. ('Hospitals and Charities,' 1898, p. 85.)

There are other activities long since existing which might well be extended. I will not dwell, as I am tempted to do, on the endowments of scholarships and the like, which aim at finding and educating the fittest youths for the work of the nation; but I will refer to that wholesome practice during all ages of wealthy persons interesting themselves in and befriending poor but promising lads. The number of men who have owed their start in a successful life to help of this kind must have struck every reader of biographies. This relationship of befriender and befriended is hardly to be expressed in English by a simple word that does not connote more than is intended. The word 'patron' is odious. Recollecting Dr. Johnson's abhorrence of the patrons of his day, I turned to an early edition of his dictionary in hope of deriving some amusement as well as instruction from his definition of the word, and I was not disappointed. He defines 'patron' as 'a wretch who supports with insolence and is repaid with flattery.' That is totally opposed to what I would advocate, namely a kindly and honorable relation between a wealthy man who has made his position in the world and a youth who is avowedly his equal in natural gifts, but who has yet to make it. It is one in which each party may well take pride, and I feel sure that if its value were more widely understood it would become commoner than it is.

Many degrees may be imagined that lie between mere befriendment and actual adoption, and which would be more or less effective in freeing capable youths from the hindrances of narrow circumstances; in enabling girls to marry early and suitably, and in securing favor to their subsequent offspring. Something in this direction is commonly but half unconsciously done by many great landowners whose employments for man and wife, together with good cottages, are given to exceptionally deserving couples. The advantage of being connected with a great and liberally managed estate being widely appreciated, there are usually more applicants than vacancies, so selection can be exercised. The consequence is that the class of men found upon these properties is markedly superior to those in similar positions elsewhere. It might well become point of honor, and as much an avowed object, for noble families to gather fine specimens of humanity around them, as it is to procure and maintain fine breeds of cattle and so forth, which are costly, but repay in satisfaction.

There is yet another existing form of princely benevolence which might be so extended as to exercise a large effect on race improvement. I mean the provision to exceptionally promising young couples of healthy and convenient houses at low rentals. A continually renewed settlement of this kind can be easily imagined, free from the taint of patronage, and analogous to colleges with their self-elected fellowships and rooms for residence, that should become an exceedingly desirable residence for a specified time. It would be so in the same way that a good club by its own social advantages attracts desirable candidates. The tone of the place would be higher than elsewhere, on account of the high quality of the inmates, and it would be distinguished by an air of energy, intelligence, health and self-respect and by mutual helpfulness.

Prospects.

It is pleasant to contrive Utopias, and I have indulged in many, of which a great society is one, publishing intelligence and memoirs, holding yearly elections, administering large funds, establishing personal relations like a missionary society with its missionaries, keeping elaborate registers and discussing them statistically with honest precision. But the first and pressing point is to thoroughly justify any crusade at all in favor of race improvement. More is wanted in the way of unbiased scientific inquiry along the many roads I have hurried over, to make every stepping-stone safe and secure, and to make it certain that the game is really worth the candle. All I dare hope to effect by this lecture is to prove that in seeking for the improvement of the race we aim at what is apparently possible to accomplish, and that we are justified in following every path in a resolute and hopeful spirit that seems to lead towards that end. The magnitude of the inquiry is enormous, but its object is one of the highest man can accomplish. The faculties of future generations will necessarily be distributed according to laws of heredity, whose statistical effects are no longer vague, for they are measured and expressed in formulæ. We cannot doubt the existence of a great power ready to hand and capable of being directed with vast benefit as soon as we shall have learnt to understand and to apply it. To no nation is a high human breed more necessary than to our own, for we plant our stock all over the world and lay the foundation of the dispositions and capacities of future millions of the human race.

THE END OF THE FILTH THEORY OF DISEASE.

By Dr. CHARLES V. CHAPIN.

FOR half a century in this country, and for a longer time in England, the filth theory of disease has dominated medical thought and has been accepted with trusting faith by the public, particularly by the better educated portion thereof. The idea that filth is the cause of disease dates back to a much earlier period. It has probably been a common belief among most civilized peoples. In colonial times many of our physicians believed in the close connection between filth and disease, and these notions sometimes found expression in laws. The prevalence of yellow fever in most of our seaboard cities during the last years of the eighteenth century did much to advance the filth theory, for this fever was held by many physicians to be *par excellence* a filth disease. The popular ideas were doubtless illustrated by the legislation enacted in Massachusetts, which provided for the summary removal of 'any nuisance, source of filth or cause of sickness.' This law has since been copied by fourteen states. The filth theory, however, did not become the vogue until the latter half of the nineteenth century. Its great popularity was largely due to the efforts of three men: Chadwick in England, Pettenkoffer in Germany and Shattuck in the United States, but doubtless most of all to Chadwick. Edwin Chadwick was a lawyer and social reformer. He was intensely humanitarian, and the misery then existent in England appealed most strongly to him. He saw that the poor people were filthy and sick, and he assumed that the sickness was due to the filth. There were some who objected that the relationship was not proved, but their objections amounted to little at a time when scientific reasoning was just beginning to find a place in medical thought. The practical reforms brought about by Chadwick and his followers in improved housing for the poor, improved refuse disposal, the introduction of drainage systems and the betterment of water supplies, certainly resulted in increased comfort, and constituted a decided advance in what we call 'civilization.' But they did not exterminate the infectious diseases as had been hoped and promised. The filth theory found strong supporters among engineers, and later among drain-layers and plumbers. These men accepted honestly enough the teaching of their medical advisers, and naturally became active propagandists of a theory which demanded such services as they alone could render.

From the middle until nearly the close of the nineteenth century, the germ theory, during the period when it was little else than a theory, furnished many arguments for those who contended that filth was a fertile source of disease. Putrefaction and fermentation were known to be similar processes, and were believed to be due to the vital activity of minute organisms. There were good grounds for believing that diseases of an infectious nature were also dependent on the growth in the body of similar 'germs,' and this theory from 1850 grew rapidly into favor. The germ theory led Dr. Farr, Registrar General of England, to classify most of the infectious diseases as 'zymotic' or fermentative diseases, for the disease poison was supposed to act, as in truth it does, as a ferment in the blood or other tissues in the body. If both putrefaction and disease were due to the action of minute organisms, what more reasonable than to believe, said the theorists, that putrefying material harbored and developed the 'germs' of disease?

The filth theory then, which has had such a powerful influence on the public mind, assumed that most of the infectious diseases were directly and specifically caused by germs or other more subtle emanations from decaying animal or vegetable matter.

Furthermore, it was claimed that while such emanations might not in every case produce a specific disease, they did tend almost always to affect injuriously the general health, and lower the vitality of persons habitually exposed. Hence the sewer gas theory which has found such acceptance, and which has taught that the gas formed from the filth in drains is so injurious to human life that portions so minute as not to be appreciated by the senses are yet harmful in the extreme. It was taught by medical men and health officials that filth and decay in every form were a serious menace to health, both from the disease germs which they contain, and the poisonous gases which they give off; and this teaching is received and accepted, even to-day, by a large portion of the medical profession, health officers and the public at large.

It is true that ever since this theory was promulgated some have been led to doubt its dicta, because in the first place they often found filth to abound where little zymotic disease existed, and even where the 'general health' of the people was high. On the other hand, zymotic diseases were frequently found in the cleanest of dwellings, and where the best of plumbing kept out all sewer gas. But most sanitary officials accepted the theory as fact, and acted accordingly, some used it simply as a working theory awaiting more definite knowledge, and a few were led by their experience to allow it little weight in their work.

As soon as the germ theory of disease ceased to be a mere theory, and the true facts in regard to the etiology of the infectious diseases began to be known, and bacteriology gave us exact knowledge of the

life history of the minute organisms which are their cause, the erroneous generalizations of the filth theory became apparent. We can now to a large extent discriminate between filth that is dangerous and that which is not. We know that the gaseous emanations from decaying matter do not produce specific disease. We know that the germs themselves are much more rarely air borne than had been thought, and that they are not thrown off into the air from the moist surfaces of the materials where they are largely found.

Observations of cholera outbreaks, both in England and this country, furnished the best arguments for the filth theory. This disease was in a great number of instances traced to wells or streams polluted with leakage from privies or drains. The disease abounded in filthy locations and among filthy people. It was perhaps natural, though not logical, to accuse all filth as likely to produce cholera. We now know that cholera is due to the comma spirillum and that this germ is thrown off from the patient in the discharges from the bowels, but that outside the body it rarely survives a few days, and practically never increases in number. Excrement from cholera patients may infect drinking water and so cause the disease, or among the uncleanly, fecal matter may be pretty directly transferred from one to another, or food may become infected by hands soiled by fecal matter, or the germs may be carried to the food by flies or other insects.

It is not filth that causes cholera, but a particular kind of filth, namely the excrement of cholera patients. Furthermore this filth and its germs are not air borne, they are not breathed in, but taken in through the mouth. This exact knowledge does away with the vague fear of all filth as a cause of the disease, and greatly simplifies the means necessary to control it. It is true that the filth theorists did much to prevent cholera, for in their warfare against filth they demanded a water supply from a source which could not be contaminated, and they demanded sewers to remove all excremental matter. These great public improvements make it far easier to control cholera than it was before their inception. The filth theorists were successful thus far, because, so far as cholera was concerned, there was a modicum of truth in their theory.

What has been said of cholera is applicable also to typhoid fever. This disease is due to a bacillus which does not grow outside of the body, but is carried in excremental filth just as is the cholera spirillum, and it must be controlled in just the same way.

The diphtheria bacillus is also strictly parasitic and grows, except in rare instances, on the mucous membrane of human beings. From persons so infected it is transmitted to others, usually by means of cups, spoons, pencils or other articles, or directly by kissing or fondling. Diphtheria was a few years ago considered a filth disease and was

often attributed to sewer gas. We now know that the only filth to be feared is the secretions of infected persons.

Bubonic plague has always been classed as a typical filth disease, but here again careful laboratory work has resulted in a vastly clearer knowledge of its causation, though a great deal yet remains to be learned. The bacillus which causes it was discovered by Kitasato in 1894; and it has been found that it rarely if ever increases in numbers outside of the body, but rather tends to die off, frequently very rapidly. There is much reason to think that fleas and rats become infected, and are important factors in the spread of the disease, though more evidence on this point is to be desired. In any event it is shown to be a contagious disease, though perhaps not usually directly contagious, and that it does not develop in filth. We might have a perfectly drained city, with modern plumbing, efficient scavenging and the purest of water, yet, if the inhabitants were careless in their habits and opposed isolation, the disease would spread as in an undrained and poorly watered city. It might require rats and fleas to cause an epidemic; but these animals played no part in the filth theory.

Tuberculosis was never classed as a filth disease, though the introduction of sewers has been held to cause its decrease, it is claimed by draining the soil. It has, however, been proved to be a bacterial disease, but the bacillus will not grow outside of the body and has no relation to filth, except so far as matter expectorated by a consumptive is filth.

Typhus fever, smallpox, scarlet fever, measles and whooping cough have by some enthusiasts been attributed to filth, but very few observant persons who have studied the distribution of these diseases and followed their outbreaks consider them other than purely contagious. They, of course, never originate in filth or develop in filth, but may spread more among filthy people just because such persons use very little soap and water and allow their faces, hands, belongings and dwellings to become and remain smeared with mucus, saliva, pus and other infectious material.

Malaria has for centuries been considered to be the product of decaying vegetable matter, but its true relation to such material has only recently been discovered. The mosquito is the bearer of the malarial parasite, which in this case is a protozoan rather than a bacterium, and the larvæ of the particular species of mosquitoes which carry this disease live only in shallow pools where they are protected from their enemies and find an abundance of food. Water which is really filthy is not congenial to them.

Yellow fever is the one disease which it has been believed could surely be traced to filth. No disease in this country is so dreaded, and its supposed dependence upon filth has made it the last stronghold of the advocates of this theory. It has been held by almost all observers

that this disease is carried in fomites, *i. e.*, lives outside of the body, and is thus implanted in new localities, where it develops in a filthy soil, giving rise to new foci of the disease. We have been taught that by keeping a city thoroughly clean, yellow fever could be excluded as it would find no place to grow. Such methods, however, never have been and never could be successful. We all owe a great debt of gratitude to Surgeon Reed and his associates for teaching us the true method of combating this disease and dealing a death blow to the filth theory. By their experiments in which they failed to transmit the disease by fomites, they showed that the poison, the exact nature of which still remains unknown, does not live outside of the body and therefore can not develop in filth. The mosquitoes which transmit this disease do, unlike the malarial mosquitoes, often breed in filthy water, such as cesspools, dirty gutters and the like, and this doubtless is the kernel of truth in the filth theory of its origin.

Thus one by one the zymotic diseases have been shown to be purely contagious, and not to have their origin in filth. In not a single one cf these diseases has our more exact knowledge placed its source outside of man or other animals. But it may be argued that though the specific diseases may not arise from filth, we still have to fear the gaseous products of decomposition, and that the foul emanations from sewers, vaults and dung-heaps may undermine the health and pave the way for these diseases. Probably more sins have been attributed to sewer gas than anything else of this kind, but we now know that the air of modern sewers and well constructed drains is practically harmless. It is true that in confined cesspools and choked drains, injurious gases like sulphuretted hydrogen, marsh gas or carbon dioxide may be formed in such quantities as to be fatal to life, but in ordinary sewers and drains, with their facilities for ventilation and rapid motion of contents, such accumulations are impossible, and a slight leakage of sewer air, which was formerly considered so dangerous, has been shown by the chemists and bacteriologists to be harmless. Foul odors from manure piles, garbage barrels, soap works or offensive manufactories are when concentrated intensely annoying and often nauseating to those who only occasionally breathe them, but those who are constantly exposed to them do not suffer at all and do not notice them. It is also observed that plumbers and sewer cleaners are not at all affected by the odors to which they are exposed. When these odors are slight there is no reason to think that they affect the health at all, and in any event the disturbance which they cause is not lasting. The burden of proof lies with those who claim that the gases of decomposition are a serious menace to health. Most of the alleged proof relates to the production of specific diseases like typhus, typhoid and cholera which we now know can not be caused in any such way. Evidence tried by modern

methods of scientific enquiry is lacking. Such evidence as we have shows that those persons who are constantly exposed to the gaseous products of decomposition do not suffer therefrom.

From whatever point of view this matter is discussed, it must not be forgotten that the advocates of the filth theory did much good, for there was a certain amount of truth in the theory. Certain kinds of filth are conveyors of specific disease, and the efforts to secure better water, to build good sewers and drains, and promptly remove excreta from dwellings were true sanitation. The providing of better houses doubtless conduces to greater personal cleanliness and tends to higher standards of living. Full credit should be given to early reformers who labored earnestly according to their knowledge, and accomplished much good and very little evil. It is only those who in the light of more accurate knowledge still hold to the crude ideas of an earlier age with whom the writer would differ.

In abandoning the filth theory we should profit by experience and not become wedded too closely to the germ theory. We do know much about bacteria and protozoa and their relation to disease, but vastly more remains to be learned, and it is much to be feared that too many seek to enter the sphere of the unknown by hasty speculation rather than by the slow path of laborious research.

Though abandoning the time honored theory which was taught him, the writer has not abandoned the fight against filth. Filth is a nuisance, and is usually an evidence of some one's carelessness of his neighbor's comfort. The state or city should certainly protect its citizens against such nuisances. Good sewerage, well swept streets, prompt scavenging, public baths, clean tenements, are all parts, desirable and essential parts, of our civilization. They would be worth what they cost even if they had no relation to health; but the proper disposal of excreta and cleanliness of person doubtless do have much to do with the prevention of the spread of many communicable diseases. Much is to be gained by promoting cleanliness, but nothing by fostering false notions of the dangers of filth.

RECENT TOTAL ECLIPSES OF THE SUN.

By Professor SOLON I. BAILEY,
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NATURE, when in her sublimest moods, is seldom seen without fear and danger. The tornado furnishes an exhibition full of weird beauty and scientific interest; yet man, in his haste to reach a place of safety, has little time for their contemplation. In the total eclipse of the sun, however, nature provides one spectacle, unsurpassed in grandeur, which may be observed in perfect safety. There was a time, indeed, when the chief emotion caused by an eclipse was fear, that superstitious dread of impending evil, which the presence of the unknown causes. This has now passed away, with the increase of knowledge. Perhaps no better illustration of the changed thought of the world in regard to natural phenomena could be found than a comparison of the following extracts. The first is from the early English chroniclers; William of Malmesbury, writing of the eclipse of March 20, 1140, says:

> At the ninth hour of the fourth day of the week, there was an eclipse throughout England as I have heard. With us, indeed, and with all our neighbors, the obscuration of the sun also was so remarkable that persons sitting at table, for it was Lent, at first feared that chaos was come again; afterwards, learning the cause, they went out and beheld the stars around the sun. It was thought and said by many not untruly that the king would not continue a year in the government.

The 'New York Herald' of January 2, 1889, announced the eclipse of the previous day with the following headlines: "THE SUN KNOCKED OUT. AFTER ABOUT TWO MINUTES IT COMES UP SMILING. VIEWING THE ECLIPSE. CLEAR SKIES ALMOST UNIVERSAL ALONG THE BELT OF TOTALITY. FINE PHOTOGRAPHS TAKEN," ETC., ETC.

Scientific study is now the chief attraction of an eclipse, although its spectacular beauty is appreciated as never before. Many natural phenomena, which otherwise would attract the systematic attention of scientists, fail to do this in consequence of the irregularity with which they occur. An eclipse of the sun, however, can be computed many years in advance, so that careful plans can be made for its observance. Even here grave trouble is caused by the uncertainties of meteorological science. It is a striking and somewhat discouraging fact that, while one can compute with reasonable accuracy the place and time of an eclipse a hundred years in advance, he cannot safely predict a single

day before the event whether the sky will be clear or clouded. Under these circumstances it is not surprising that many people do not travel to the scenes of total eclipses. Expeditions to eclipses were practically unknown until half a century ago. Before that time man received with varied emotions those which Providence sent him, but did not travel far to seek them. Now, expeditions half way round the earth are common. This is not due entirely to the greater scientific zeal of the present day; probably few living astronomers would care to journey to the antipodes for an eclipse, under the conditions of travel which prevailed one or two centuries ago.

About seventy total eclipses of the sun occur each century. The average duration is, perhaps, three minutes, which amounts to about three and a half hours per century. If some Wandering Jew, at the beginning of the Christian era, had started to observe total eclipses of the sun, and had visited every one possible since that time, he would have had less than three whole days for observation. The time, indeed, would have been much less, since many of these eclipses occurred on the ocean, or at inaccessible regions of the earth, and clouds undoubtedly obscured the sky during half the time of totality. During the last half century, since spectroscopic observations have been carried on, the time during which an individual could have obtained favorable observations has been little, if any, more than a single hour. Under these circumstances the wonder is that it has been possible to accomplish so much. Many men, however, have worked at different stations along the narrow but extended path of totality, and every device which ingenuity could suggest has been utilized in order to obtain as much as possible in the brief seconds of totality. Nothing has contributed so much to increase the amount and accuracy of the results as photography. There is hardly a line of investigation which cannot be done more quickly and better by photographic than by visual methods. Nevertheless it would be a mistake to abandon visual observations altogether.

It may hardly need to be stated that for the most part scientific observations of total eclipses have for their object the promotion of our knowledge about the sun. No one, who understands at all how intimate is our dependence upon that great body, will question the wisdom of such efforts. In order to understand why certain problems can be better studied when the sun's face is covered by the moon, it may be well to outline our knowledge on the subject.

The sun, the center of our system, is an exceedingly hot, intensely bright, highly condensed, gaseous body. Its distance is a little less than 93,000,000 miles. Its volume is more than a million times that of the earth. Its specific gravity is somewhat greater than that of water. A gaseous body, denser than water, is something very different

from our ordinary conception of a gas. That which we see, which gives the sun its apparent size, which sends us our light, is known as the photosphere. This is probably a brilliant shell of metallic clouds floating in an atmosphere of vapors of the same materials. There are certain details in this photosphere with which we are familiar, such as bright patches, known by different names, and sun-spots. For convenience we may regard this photosphere and all that it contains as *the Sun,* and all that lies outside this shell as the solar *atmosphere.* With the sun itself we have little to do in this article, since it can be better observed on any clear day than at time of eclipse. It is, however, only at time of total eclipse that we clearly see all those strange and complex features which make up what we have called the solar atmosphere. In our study of it, however, we must not be governed too much by any analogy with our own atmosphere. Lying next to the body of the sun is a layer of crimson flame, known as the chromosphere, which has a thickness of perhaps 5,000 or 6,000 miles. This may seem like a great depth for such a sea of fire, but compared with the enormous size of the sun it is very small indeed, and forms but a thin rose-colored rim about the edge of the sun. At the bottom of this is probably the so-called reversing layer. The solar spectrum is crossed by dark lines due to the elements which there exist. By these dark absorption lines, which are seen in the ordinary solar spectrum, the presence is known of many familiar elements. The higher regions of the chromosphere are less complex and consist in large part of hydrogen. From these regions, by forces which there operate, great masses of brilliant colored gas are thrown upward to enormous distances, in general 10,000, or 20,000 miles, but often much higher, even to 200,000 or 300,000 miles. Resting also on the photosphere is the corona, which extends its pearly light outward from the sun to immense distances which must be reckoned in millions of miles.

The different parts of the solar atmosphere are brightly luminous, and stand forth in splendid beauty at the instant of totality. The only reason why we do not see them on any clear day is that they are lost in the blinding light of the central sun. The sun's face must be shut out. This service is rendered by the moon at an eclipse. At other times the chief trouble is not that the sun shines directly into our eyes, since a piece of cardboard could be so placed as to cut off the rays. The real difficulty arises from the presence of our atmosphere, which becomes so bright from the diffused light of the sun, that the solar appendages are lost to view. This will be apparent from the daily phenomenon of the appearance by night, and the disappearance by day, of the stars. They are shining just as brightly by day as by night, and could be seen perfectly well if the atmosphere were removed for a moment.

One of the most successfully observed of recent eclipses was that of May 28, 1900. The duration of totality was only two minutes, but almost perfect weather prevailed everywhere. It was visited by a large number of skilled observers, and an examination of the work performed and attempted will give a good idea of what astronomers at the present day hope to learn about the sun at times of total eclipse. As stated above, the ordinary solar spectrum consists of a bright band crossed by dark absorption lines due to a reversing layer present in the chromosphere. At the eclipse of 1870, Professor C. A. Young, who was watching the spectrum of the fast disappearing sun, saw, at the instant when the last bit of the photosphere was covered by the moon, the solar spectrum with its dark lines replaced by a spectrum composed of bright lines. This phenomenon, from the suddenness of its appearance became known as the 'Flash.' The 'flash' spectrum is one of the most interesting features of a total eclipse. The depth of the flash layer is very small, and the duration of its greatest intensity very brief, since it is covered by the moon after two or three seconds. To obtain good photographs of this phenomenon is somewhat difficult. This has been accomplished, however, at the eclipses of 1896 and 1898, and, especially, by several observers, at the eclipse of 1900. Several kinds of spectroscopes are in use. Ordinarily an astronomical spectroscope consists of a telescope, a narrow slit, a train of prisms, and a small telescope which brings the spectrum to the eye or to the photographic plate. When the object which is to be examined has an area like the sun the use of a slit cannot be avoided. When the source of light is a point, or a narrow line of light, there is no such necessity and the more simple apparatus, known as the slitless spectroscope, or objective prism, may be used. This consists of a prism placed over the lens of the telescope and a photographic plate at the focus. Instead of the prism or prisms a diffraction grating may be used. Professor Pickering, the director of the Harvard Observatory, has obtained for many years fine spectra of the stars by this method, which is an adaptation of the original method of Fraunhofer. An apparatus of this sort used in eclipse work is known as a 'prismatic camera.' It is evident that this form of spectroscope could not be successfully used on the uneclipsed sun, since the resulting spectrum would be simply a confused mass of colored light. There must be a slit, but in the case of total eclipse, nature furnishes it. As the moon at such times has an apparent diameter greater than that of the sun, it is readily seen that at the instant before the moon's disc completely covers the sun there will remain a very narrow crescent of light. At the instant after totality has begun the photosphere will be entirely covered, but for two or three seconds the thin line of chromospheric light remains in view. The two spectra taken at these moments, the one an instant before

Fig. 1. Solar Spectrum. 10s after Totality, Enlargement. Made by Professor E. B. Frost. Eclipse of May 28, 1900.

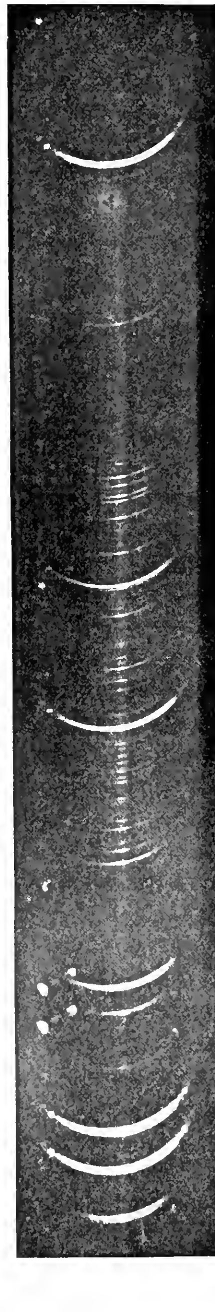

Fig. 2. Flash Spectrum at Second Contact. Made by Professor Frost. Eclipse of May 28, 1900.

and the other an instant after, the beginning of totality have been called the 'cusp' and the 'flash' spectrum. A similar pair occur, of course, when totality ends, but in reverse order. Figure 1 shows an enlargement of a portion of the cusp spectrum at third contact. This photograph was made by Professor E. B. Frost, of the Yerkes Observatory, at the eclipse of 1900. It furnishes an opportunity to compare directly the dark lines of the ordinary solar spectrum with the bright lines of the chromosphere. It is of the greatest interest to learn whether the two series of lines are identical, in whole or in part, though reversed, and in any case to study the characteristics of these bright lines. This photograph was made about ten seconds after the end of totality. The thin line of the photosphere, which had then emerged from behind the moon, was drawn out by the prism into the bright band, which constitutes the larger portion of the picture. This is the ordinary solar spectrum. It will be noted that while in spectra as usually seen the lines are straight, since a straight slit is used, here the lines are arcs, since nature furnishes a crescent of light. An examination of these dark arcs shows that in nearly all cases they become bright lines at the upper edge of the spectrum. This 'reversal' is due to the fact that just beyond the point where the crescent of sunshine ceased, was a small extension of the chromosphere, which was not covered by the moon. The precise determination of all the facts, which this and other similar photographs teach, is one of the important problems of total eclipses. The problem is somewhat complicated, as pointed out by Professor Frost: for although few dark arcs can be seen which do not terminate in a bright tip the curvature and position appear to be slightly different in some cases for the bright lines. Figure 2 shows the 'flash' spectra made at the second contact, that is, at the beginning of totality. The sun is entirely hidden by the moon, and all the lines which appear are doubtless due to the chromosphere. Certain irregularities, or 'bunches,' in the arcs, however, are due to solar prominences. From an examination of these and other photographs Professor Frost has measured and identified several hundred lines, and has reached the following conclusions: "At least 60 per cent. (and probably many more) of the stronger dark lines of the solar spectrum are found to be bright in a stratum not exceeding (for the majority of the lines) 1″, or less than 500 miles in height above the solar photosphere. There is moreover no reason in general to suppose that this is not equally true of the fainter lines. Therefore we may regard the existence of a reversing layer at the base of the chromosphere as fully confirmed by the photographs." These results are especially important since they contradict to some extent those which have been previously obtained. While the elevation of the strata which produce the most of the lines is less than 500 miles, the height of other gases

above the photosphere is as great as 4,000 miles. The bright lines are identified as belonging to iron, titanium, chromium, hydrogen and other elements. The origin of some of the lines is unknown.

Although no other time may be so favorable for the study of the reversing layer as at total eclipses, the chromosphere and prominences may nevertheless be well studied on any clear day.

In connection with the eclipse of 1868 Janssen and Lockyer each independently discovered that by spectroscopic means the light of the chromosphere and prominences may be so separated from that of the sky as to become visible without an eclipse. The light from the region just outside the sun's limb is composed of skylight and the light of the solar atmosphere. Each is about equally bright. When this combined light is passed through a prism, that due to the sky is spread out into a continuous surface, thus becoming much fainter, while that due to the chromosphere or prominence, from its gaseous nature, is collected into bright bands, which thus surpass the skylight in intensity and may be seen or photographed. This line of work has been

FIG. 3. GREAT ERUPTIVE PROMINENCE. WITH HALE SPECTROHELIOGRAPH. MADE MARCH 25, 1895, 10h. 34 m. A.M.

FIG. 4. GREAT ERUPTIVE PROMINENCE. WITH HALE SPECTROHELIOGRAPH. MADE MARCH 25, 1895, 10h. 58m., A. M.

greatly extended by different scientists, notably by Hale, of this country, who, by a device known as the spectro-heliograph, has succeeded in making, without an eclipse, photographs showing all the prominences surrounding the sun and the details of the solar surface at the same time. These photographs are made in monochromatic light. They represent what would be seen if the eye were sensitive to light of the wave-length of the K line only. Figures 3 and 4 show a great eruptive prominence photographed by Professor Hale, March 25, 1895. The interval between the two photographs was 24 minutes, during which time the prominence was thrown upward from a height of

135,000 miles to 281,000 miles. This implies a velocity of at least 100 miles per second.

At times of total eclipse it is perhaps possible to obtain better photographs showing finer details than can be made under other conditions. Figure 5 is an enlargement of a photograph made at the eclipse of 1900, by Professor E. E. Barnard, assisted by Mr. G. W. Ritchey. It shows a mass of prominences at the southwest quadrant of the sun. Along the irregular limb of the moon, which appears black, is seen the ragged storm-tossed surface of the chromosphere, of increasing depth toward the right owing to the moon's position at the instant of the exposure. Thrown up from this are the vast fantastic masses of the prominences or 'red flames.' They remind us of pictures which show the effects produced by the explosion of submarine torpedoes. The larger mass at the left rises to the height of 60,000

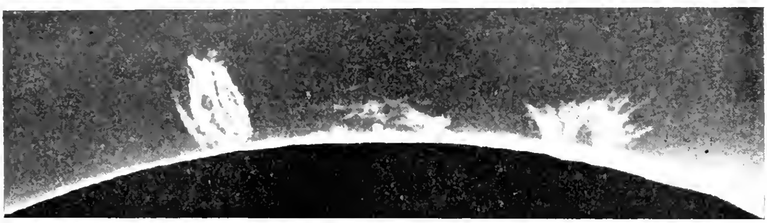

FIG. 5. SOLAR PROMINENCES. ECLIPSE OF MAY 28, 1900. PHOTOGRAPHED WITH A TELESCOPE OF 6 INCHES APERTURE AND 6½ FEET FOCUS, BY PROFESSOR BARNARD AND MR. RITCHEY.

miles. This photograph was made with a telescope of only six inches aperture and six and a half feet focal length, a small instrument compared with some which have been used at recent eclipses. The writer has seen no other photograph of prominences, however, which, in delicacy of detail, surpasses the one here shown.

The single feature of a total eclipse which can be seen and studied only at such times is the corona. In early ages small mention was made of the corona. Apparently the dread of impending evil overwhelmed man, and prevented careful observations. As fear disappeared and scientific interest grew, attention was drawn to the 'red flames,' and at nearly the same time to the beautiful halo of light which has been fittingly named the 'corona.' Since that time the favorable moments of totality have been too few to clear up the mystery of its nature. Reasoning from the methods which have made the study of the chromosphere and prominences possible without an eclipse, various attempts have been also made to thus observe and photograph the corona. The simplest way would be by direct vision or photography. There is no doubt but that, if we could remove for a moment the earth's atmosphere, whose glare interferes with our vision, we

should be able to see the chromosphere, prominences and corona without any artificial aid. The brightness of the inner corona is about the same as that of the ordinary sky near the sun. If then one could find

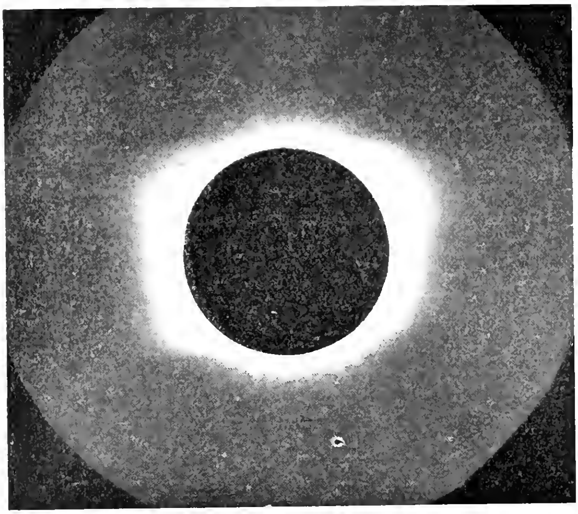

FIG. 6. SOLAR CORONA. ECLIPSE OF 1889. NEAR SUNSPOT MINIMUM. HARVARD ECLIPSE PARTY, WILLOWS, CALIFORNIA.

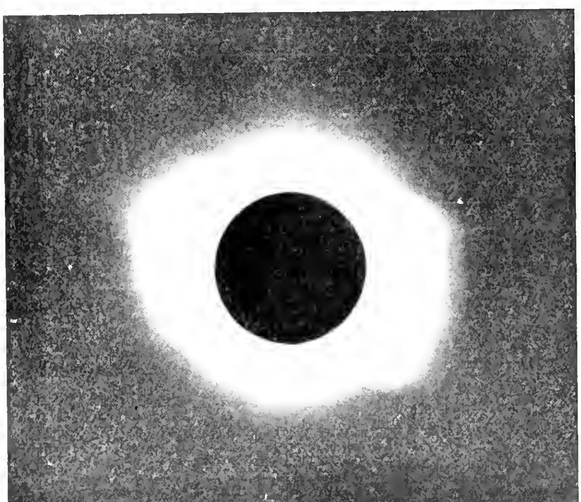

FIG. 7. SOLAR CORONA. ECLIPSE OF 1900. NEAR SUNSPOT MINIMUM. MADE BY MR. C. A. R. LUNDIN AT SOUTHERN PINES, N. C.

a locality where the sky was extraordinarily clear, he might hope, by placing a shield in front of the sun itself, to see these fainter features. The writer of this article made an attempt several years ago in this

way on the summit of El Misti, Peru, at an elevation of 19,200 feet. At this altitude one-half the earth's atmosphere is below the observer and that which remains is of extraordinary clearness. Photographs were made of the region immediately about the sun, using an opaque disc to protect the plate from the sun's direct image. The true corona did not appear upon the plates. Other methods promised better results, such as the use of monochromatic light, presumably that of the line 'K 1474.' Experiments in this line have been carried on by Professor Hale with skill and enthusiasm on the summit of Pike's Peak, on Mount Etna and elsewhere, but without success. He has also attempted to solve the difficulty by a study of the heat, using the bolometer. Recent investigations given below explain the failure

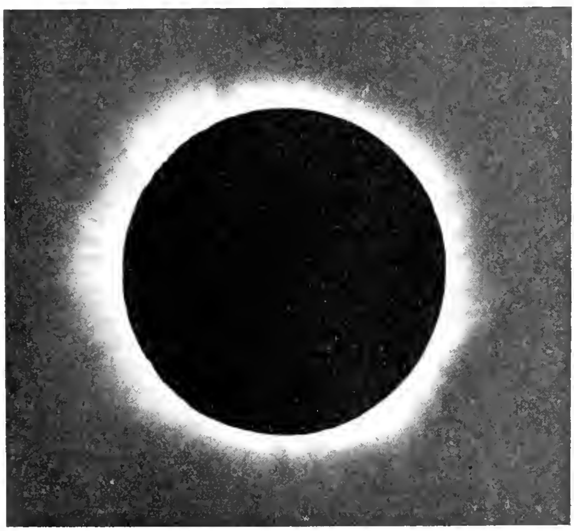

FIG. 8. SOLAR CORONA. ECLIPSE OF 1893. NEAR SUNSPOT MAXIMUM. MADE BY PROFESSOR J. M. SCHAEBERLE, LICK OBSERVATORY.

of this method. The polarization of the coronal light also suggests a method which has not yet yielded successful results. Although the future may furnish the solution, none of the attempts yet made has been successful, and for the present our only knowledge of the corona must be obtained from what can be learned during the brief moments of total eclipses. Good photographs of the corona can be easily and rapidly made and if an abundance of these were alone necessary our knowledge would be well advanced. The general features of the corona have a certain permanence. Comparatively slight changes are known to take place during the three or four hours while an eclipse is passing over the surface of the earth. There may be, however, finer details than are shown on the best photographs yet obtained, which

would give witness to more rapid changes. From year to year large changes in the form of the corona occur and these appear to be associated with the sun-spot period. This is a natural inference, especially since the solar prominences are thus associated. This is well shown by a comparison of the form of the corona in 1889 and 1900, which occurred near the sun-spot minimum, with the form in 1893, which was near sun-spot maximum. These are given in Figures 6, 7 and 8. The equatorial streamers and the divergent polar streamers are much more pronounced at the time of sun-spot minimum. At maximum the corona is more nearly circular. The polar streamers are beautifully shown in Figure 9, a photograph made by the eclipse party, which was under the direction of Secretary Langley, of the Smithsonian Institution. The true nature of the corona and the complex changes which it undergoes are unknown. The spectroscope is the magician's wand which science generally uses to reveal the constitution of unknown objects, but in this case the revelation is only partial. In 1869 Professor Young found the spectrum to be characterized by a bright line in the green, which he identified as Kirchhoff's line 1474. The unknown substance which produces this line has been given the name 'coronium.' There are also other less conspicuous bright lines. When the name 'helium' was assigned to the origin of certain lines in the solar spectrum, no such terrestrial substance was known. Later it was found by Ramsay. A similar issue for coronium would be very acceptable. The corona also yields a faint continuous spectrum, in which Janssen and others have reported certain dark lines of the solar spectrum. This signifies, that in addition to luminous gases, giving a spectrum of bright lines, the corona contains some substance, like a cloud, which is capable of reflecting ordinary sunlight. A part of the light appears to be polarized. It is thought by some observers that there is also a bright continuous spectrum free from dark lines. If true, this would imply a three-fold origin to the coronal light. For the explanation of the corona we have the diffraction theory of Hastings, the mechanical theory of Schaeberle, the magnetic theory of Bigelow, and others. The complete solution of the problem is of the greatest difficulty and of the greatest importance. At the eclipse of 1900 some experiments with that remarkable instrument, the bolometer, appear to throw new light on this subject. These experiments were made by Secretary Langley's chief assistant, Mr. C. I. Abbott, who reached the following conclusions:

These observations indicate not only that the coronal radiation is very slight, but that the *apparent* temperature of the inner corona is below 20° C. For it will be noticed that the bolometer *lost heat by radiation to the corona,* as evidenced by a negative deflection. Hence, when we consider its visual photometric brightness at the point where the bolometric measures were taken,

which, judging by the results obtained by several observers during the eclipses of 1870, 1878, and 1898, was at least equal to that of the full moon, it is difficult to understand how the light of the corona can be due largely to reflection of rays from the sun, or even to the incandescence of dust particles, for from sources of these kinds, which emit a great preponderance of invisible infra-red rays, the bolometer would have given large positive deflections. . . The important result of a comparison of the radiations of the inner corona, the full moon, and the daylight sky somewhat remote from the sun is that while the three are roughly of equal visual brightness, the corona is effectively a cool and far from intense source, while the moon and sky are effectively warm and many fold richer in radiation. Hence it would appear plausible that the corona merely sends out visible rays and that its light is not associated with the great preponderance of long wave-length rays proper to the radiation from bodies at a high temperature. If this be so the coronal radiation might be compared with that from the positive electrical discharge in vacuum tubes, in which, as researches of K. Angstrom and R. W. Wood have shown, there is neither an infra-red spectrum nor a high temperature.

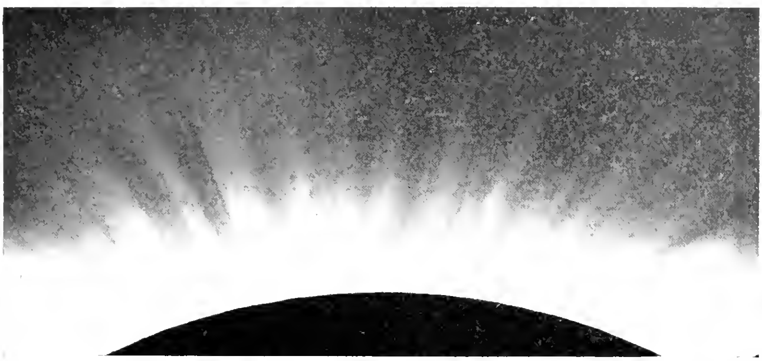

FIG. 9. SOUTH POLAR STREAMERS. ECLIPSE OF 1900. PHOTOGRAPHED WITH A TELESCOPE OF 135 FEET FOCAL LENGTH BY MR. SMILLIE, OF THE SMITHSONIAN ECLIPSE PARTY.

These conclusions are of so great importance that it is very desirable that the observations upon which they depend should be repeated at other eclipses. It is, therefore, very unfortunate that Mr. Abbott at the recent eclipse at Sumatra was prevented by clouds from carrying out the observations which he had traveled so far to obtain. Other observers, however, were no more fortunate. Professor E. E. Barnard was provided with a telescope of 61½ feet focus, and with plates forty inches square, but was prevented by clouds from obtaining results of much value. This was the fate, also, of many other observers from different countries, who had taken stations in different parts of Sumatra. Results of value were obtained, however, by the party from the Massachusetts Institute of Technology, whose photographs of the corona are unsurpassed. At the Island of Mauritius, also, the English astronomers obtained valuable results. As a whole

the eclipse of 1901 probably failed to add much to our knowledge of the sun.

Aside from the problems relating to the sun's constitution, there is still outstanding the question as to the existence of an intra-mercurial planet. This problem can be studied to much greater advantage at total eclipses than at other times. Photographic charts can be made of the whole region about the sun during totality. An examination of several sets of such photographs, taken at different eclipses, should confirm or refute the existence of such a planet. For greater certainty the sky should be photographed in duplicate at each eclipse. Although sufficient material for the decision of this question could apparently be accumulated rapidly, this has not yet been accomplished for a variety of reasons. At the eclipse of 1900, several parties were provided with apparatus especially planned for this work. The weather was everywhere perfect, but accidents of one kind or another affected the results. The Smithsonian party, however, obtained photographs, one of which showed stars fainter than the eighth magnitude. Several suspicious objects were found on these plates, which remain unconfirmed, owing to the failure of other attempts. This and other questions, which, it was hoped, would be decided by the eclipse of 1901, must await some later eclipse for their solution.

To-day, although much is known about the sun, its deeper secrets are yet unraveled. The foundations of physical science appear, indeed, to be somewhat shaken. It is hinted that molecules and atoms are, after all, but 'convenient fictions,' signifying, perhaps, that the human mind is not capable of grasping the ultimate conditions of matter. We hear of corpuscles, which are inconceivably small 'fragments of atoms.' These corpuscles are carriers of electricity. It may be that in this line lies the explanation of many terrestrial, solar, and even cosmical, phenomena.

FRIAR BACON

Engraved from the original Picture in the [illegible]

[illegible] 1st May 1790 by [illegible]

FRIAR ROGER BACON.

BY EDWARD S. HOLDEN, LL.D.

A RECENT perusal of the published works of Bacon leads me to attempt to set forth, in this place, something of his life and of his times. He is, beyond a doubt, one of the great illustrations of our race. Let us in the first place set down the facts of his checquered life in a story, without seeking too deeply for the causes of his defeats and perils. It will be time enough to examine the reasons when we know the results. He was born of a good and wealthy family, in England, between the years 1210 and 1215. He first appears in history in the year 1233. King Henry the Third had just listened, at Oxford, to a long sermon and to reprimands from a relative of Bacon's—probably an uncle—who charged the king to dismiss from his council Pierre Des Roches, Bishop of Winchester, who was hated by the English. A young clerk—it was Bacon—dared to address the king with this audacious raillery, says Matthew Paris in his chronicle.

"Seigneur Roi, savez-vous les dangers qu'on a le plus à redouter quand on navigue au-delà de la mer?

"Ceux-là le savent, répartit Henri, qui ont l'habitude de ces voyages.

"Eh bien, je vais vous le dire, reprit le clerc, ce sont les *pierres* et les *roches*—et il voulait désigner par là *Pierre* Des *Roches*, l'évêque de Winchester.'

Bold and reckless speaking regardless of consequences was a life-long characteristic of Bacon, and the first and only anecdote that we have represents him bold with kings, as he afterwards was bold towards popes, cardinals, generals of his order, doctors of the church and the society in which he lived. It may, for a moment, seem to us tc be a merit. In sad fact, it was never so in his life, and it led to his undoing.

He learned this temerity from a great man who was his master at Oxford and afterwards the illustrious Bishop of Lincoln, Robert Grossteste, the first English scholar of his time—he who browbeat the pope and called him 'heretic' and 'anti-Christ.' Robert was Superior of the Franciscans at Oxford and lectured there on optics. Athelard of Bath, the first translator of Euclid, was not forgotten in those schools, which were then marked by great intellectual freedom and by a strong leaning towards science.

Here Bacon passed years in ardent research. He mastered all the book learning of the schools—philosophy and mathematics: and ex-

pended, he tells us, something like £2,000 (probably French pounds) in his experiments in natural philosophy, chemistry and astronomy. Experimental science was a new thing and Bacon may well claim to be its founder, though Ptolemy experimented on refraction, Galen on the nerves and muscles and the Arabs in various branches of science.

About the year 1240 Bacon became a friar of the order of St. Francis. If he had seen clearly, his career was made. Albertus Magnus and his great pupil, Thomas Aquinas, were the lights of the Dominican Order. The Franciscans would have welcomed and honored a champion who was the superior of Albert and the equal, or almost the equal, of Aquinas. But Bacon had only rough and bitter criticisms for all monks—Franciscans and Dominicans alike. His was an original and hardy genius; and he proved himself a merciless critic of all celebrities, of every accepted method and conclusion. Alexander of Hales, *Doctor Irrefragabilis,* was the oracle of the Franciscans. Of his *Summa Theologiæ,* Bacon says: It was a load for a horse—true—but—the reputed author did not write it. Albertus Magnus wrote libraries of books: All of them that were of any account, says Bacon, could be put in a single volume. Aquinas is *vir erroneus et famosus.* Of the other doctors, Michael Scot, he says, knew no Greek, Gerhard of Cremona, not even Latin, and William of Morbecke, the friend of Aquinas, was the most ignorant of all. St. Augustine and Origen were full of errors, and St. Jerome did not always understand the scriptures he translated.

"Never was there so great an appearance of wisdom, nor so much exercise of study as for this last forty years. Doctors are everywhere, in every castle, in every burgh, especially the students of the two Orders (Franciscan and Dominican). And yet there never was so much ignorance and error." He condemned the current versions of Aristotle—retranslations from the Arabic of translations once made into Syriac by Nestorian monks. "The common herd of students," he says, "mope and make asses of themselves over their bad translations and waste their time, their trouble and their money." In fact, he declares, "What the mass of men believe is necessarily false." As for the works of Aristotle, he would burn them all.

It is no wonder that Bacon was disciplined and imprisoned in Paris during the years 1257 to 1267. How severe his punishment was we shall never know. A part of it was rigorous. He was forbidden books and copyists, kept on bread and water. At times, however, he had pupils, copyists and some slight degree of liberty. He was condemned by a council of his order *propter quasdam novitates suspectas*—in reality because his harsh and innovating spirit diffused uneasiness all about him. It is charitable if we do not pronounce him envious. With Albertus Magnus and Aquinas he made up a trio of really great men,

but he has no good words for either of them or for their works and ways. The men of no century have listened willingly to criticism delivered in this temper. That his strictures were substantially just did not make them more acceptable in Bacon's case, nor four centuries later, in the case of Galileo. It was of no avail that his life was pure, that he had not sinned against the faith, that he had not rebelled against authority. His real offence was the censorious temper which made him enemies on every hand.

A new opportunity came to Bacon with the election of Guy Foulques (Clement IV.) to the papacy. The new pope had been a soldier, a learned jurisconsult, and Secretary of Saint Louis, before taking religious orders. While he was legate of the reigning pope in England he heard that Bacon was writing a treatise on the reformation of learning, and on many occasions he endeavored to communicate with him by letters which were intercepted by the Franciscans. In the second year of his own pontificate (1266) the new pope, Head of the Church, succeeded in sending a letter to Bacon by private hand. The letter orders Bacon "in the name of our apostolic authority and notwithstanding any injunctions to the contrary from any prelate whatsoever, and notwithstanding the constitution of your Order, to send, without delay, a copy of the work for which we asked at the time of our legation into England"; and the pope especially charges his correspondent that all this should be done "with all the secrecy possible." What a commentary upon the strictness of Bacon's imprisonment is this letter from the Head of the Church, the successor of St. Peter, with power to bind and loose! If it exhibits the persecution of Bacon, the power of the Orders, the penances of fasts and macerations, the misery of the prisoner, it also exhibits in the best and strongest light the existence in the Church of enlightened and generous spirits. Everything in the picture is not dark.

Bacon was released in 1267 by order of the pope who had then received his *Opus Majus,* and he returned to Oxford to find his group of noble friends dispersed or dead. Here he resumed his studies, his writings, his criticisms, his bitter and censorious polemics.

His protector, Clement IV., died in 1268 and the new pope soon had good reason to distrust the English friar. Bacon vehemently attacked the orders, the pope, the court at Rome, the prelates, the laïcs, the clerks, the doctors of the Church, the theologians. He swept the world clean of friends and followers. "Consider," he says. "every rank of society and you shall find an infinite corruption everywhere, beginning at the summit. The court at Rome is dominated by the Civil Law * * * this sacred seat is the prey of crime and deceit, justice is perishing, peace is violated, pride reigns, avarice burns there, gluttony corrupts manners, envy eats their hearts, luxury

dishonors the entire Court of the Papacy. * * * And the prelates! consider how eager they are for riches, how indifferent to the care of souls, * * * The religious (of the orders) are no better, and I except no Order whatsoever. * * * This people of clerks are a prey to pride, luxury and avarice. Everywhere, as at Paris and Oxford, they scandalize the laïcs * * * by their vices."

What remedy for this horrible state of things? What examples of holy living and dying does Bacon put forth for imitation? Why, the ancients like Zeno and Seneca, pagans all, and infidels like Avicenna, Alfarabius and the rest! We seem to hear the murmurs of the Renaissance in the words of this monk of the thirteenth century. If the church will not purge herself of evil he predicts the coming of the Tartars or the Saracens. In reality he was foretelling the Reformation. Terrible words like these led to his own imprisonment, again at Paris, in the year 1278. This time his punishment was strict. He was not released until a liberal general of his Order sent him home in 1292, an old man of some eighty years, to die in peace at Oxford.

The story of his life is told. Henceforward we are concerned only with the debt which modern science owes to him. But there are two errors into which we must not fall. In the first place those dark ages were not without illumination. Consider the group of great and liberal men who were Bacon's companions at Oxford in his early years, and that other group of free spirits at Paris. Consider the patience with which a pope tries for years to lighten his lot and the generosity with which he sets him free at last. Consider that the same history is almost exactly repeated by the enlightened general of his order who releases him in 1292.

And, again, let us see what were, in all likelihood, the suspect novelties for which he was punished. Like all the great and small of his time Bacon believed in astrology—in the influence of the stars upon the destinies of men. Was not christianity itself ushered in by the portent of the Star of Bethlehem? An idea adopted from the Arab Albumazar, that the advent and continuance of religions depend upon the conjunctions of the planets, was his ruin. Christianity came in, he said, with a conjunction of Jupiter and Mercury, and all religions were to disappear at a future conjunction of Jupiter and the moon. This is the suspect novelty for which he was condemned by a chapter of his order; and who shall say that he was not justly condemned? If it were allowable in a superstitious age to cast horoscopes and to reckon up the influence of stars upon the fate of individuals, it would have been monstrous and suicidal for the church to agree that religions were subject to purely natural laws and conjunctions. No church could fail to strike home when threatened with

extinction in this material fashion. Bacon is no martyr of science. He was punished for an attack on the very nature and existence of the church itself; for setting up a natural law to govern and limit the things of the spirit.

Owing to the horror which was felt by the writers of that age for the heresies of Bacon, his influence was very small. While Albertus Magnus was entertaining kings, and while Aquinus was the honored expounder of ecclesiastical doctrine, their contemporary and peer was languishing in confinement. His immense work was done in spite of his disgrace. His pupils received his doctrines and through them his ideas gained currency. His writings are scarcely mentioned by the authors of the fourteenth and fifteenth centuries, but we know of at least three cases in which they exerted a profound influence. The admirable doctrine of optics set forth in his work on perspective was known to Descartes, beyond a doubt, and cannot have failed to direct the thoughts of the philosopher to whom we owe the foundation of our modern theories. Again, Paul of Middleburg was deeply concerned with the reform of the calendar, and in his treatise on the subject made great use of Bacon's writings. It was Paul that suggested to Copernicus the need of more accurate tables of the planets, and we may fairly say that Bacon's labors came to fruition in the heliocentric theory of the world. Finally, a long passage in his *Opus majus,* treating of the probable proximity of Spain and India, was literally transferred (without credit) to the Imago Mundi of Peter d'Ailly. It is Columbus himself, in a letter to the King and Queen of Spain, who cites this passage as one of the authorities that put it into his mind to venture on his great voyage. Truly ideas do not die, and those of Bacon have made great changes in this little world of ours.

We may pass over his influence upon the metaphysical controversies of his time, though it was not small. He was thoroughly versed in scholastic dialectic and was much concerned to combat the pantheistic theories of Averroës and his school. He is of the strictest sect of the Nominalists, with a reasonable practicality all his own. "The prevalent view," he says, "is that universals exist only in the mind. Yet two stones would be like one another even though there should be no mind to perceive them. But it is precisely this likeness of the two stones that constitutes their universal." How modern it sounds! How crisp and neat, like a French logician. With Bacon as with others whom we call the ancients, we perpetually meet the modern note. *A man's character is his fate* was not written by Taine or Stendhal, but by Heracleitus five centuries before the Christian era.

Bacon proposed to Clement IV. the reform of the calendar in sagacious and artfully presented terms. He points out to the pope the errors of the accepted lunar tables, and proves that after a series

of years the moon will be a full moon in the sky, but a new moon in the calendar. Nothing could be neater than the presentation of this dilemma.

Bacon understood the theory of vision, the anatomy of the eye and much of the physiology of perception, as well as the theory of lenses and of the simple microscope. He did not combine two lenses to make a telescope, but he was on the high road to it. His works on alchemy were undertaken in the same scientific spirit, though in the infancy of chemistry they led to few results of value. Gunpowder he knew, very likely through the Arabs or the Greeks of Constantinople, who had it from the east. The children of his time played with it, he says.

No better example of the experimental method imagined and extolled by Bacon can be given than an analysis of his brilliant demonstration of the nature of the rainbow. Let the experimenter, he says, first consider the cases in which he finds the same colors; as in the hexagonal prisms of Iceland spar, for example. By looking into these he will see the rainbow hues. Many think that these arise from some special virtue of the stones, or from their hexagonal figure. Let the experimenter therefore go on and he shall find the same colors in other stones of other shapes, as well as in the drops of water dashed from oars in the sunshine, and the like. All these are instances like the phenomenon of rainbow colors. With regard to the form of the bow he is still more precise. He bids us measure the altitude of the bow and of the sun and note that the center of the bow is exactly opposite to the sun. He explains its circular form—its independence of the form of the raincloud—its moving when we move—its flying when we follow—by its consisting of reflections from a vast multitude of minute drops of rain. In the iris shown by the spray of a waterfall we may see the whole circle. In the sky the plane of the horizon comes in to interfere. Each drop of rain in the cloud is to be regarded as a spherical mirror.

His views of the nature of force are expansions of those held vaguely by Democritus and Lucretius. A body is a center of force from which energies radiate in every direction. Every action is accompanied by a reaction, and there is an interchange of force between all bodies of the universe. The propagation of force, of light for example, requires time. "There is no substance on which the action involved in the passage of a ray may not produce a change. Thus it is that rays of heat or sound penetrate the walls of a vessel of gold or brass. In any case, there are many dense bodies which altogether interfere with the visual and other senses of man so that rays cannot pass so as to produce an effect on human sense and yet, nevertheless, rays do really pass, though without our being aware of it." These precise statements were mere words to his contemporaries and could not

have been completely understood before the beginning of our own century. The note is that of Count Rumford or, at earliest, of Newton and Huyghens.

That learning might be reformed, he proposed the study of the comparative grammar of Greek, Arabic, Latin and Hebrew, the assiduous collection of ancient manuscripts and the ardent study of the classics. Here is the distinctive note of the Renaissance. But if the study of ancient books be so important how much more imperative is the study of the book of Nature!

I call experimental science, says Bacon, that which neglects argumentation; for the strongest arguments prove nothing so long as they are not verified by experience.

Experimental science does not receive truth from the hands of the higher sciences; it is she who is the mistress; the others are but her handmaids.

She has the right to command; for she alone certifies and consecrates their results.

Experimental science is then the Queen of the sciences and the limit of all speculation.

Physicists should know that their science is impotent if they do not utilize the power of mathematics, without which observation grows weak and incapable of any certitude.

These sentences selected at random out of whole chapters epitomize the teachings of Francis Bacon three centuries later and bring us near to the viewpoint of Helmholtz or Lord Kelvin.

Bacon had already begun the application of his absolutely new method and he has a clear vision of what may be accomplished in the future. After the mere facts of nature are discovered, he says, the laws back of the facts will be brought to light. When they are once known, the work of speculation will be completed. Man is to be the master of the world and his will is to govern. "Machines will be invented to navigate the seas without rowers; to traverse the land with unimaginable velocity; to fly with artificial wings; to walk on the bottom of the seas without danger; to bridge rivers without piers or columns." We are yet very far from a complete conquest of nature, but the nineteenth century has seen the accomplishment of each of these visions of the astonishing monk of the thirteenth.

The entire work of Bacon is summed up in two insights of widely different character and of the first importance. Either of them is a title to enduring fame. He was the first of men to expose the essential infertility of scholastic philosophy; and he was the originator of the inductive methods that characterize modern science. If we set down in detail the matured judgments of our own time upon the scholasticism of the thirteenth century we shall find that each and every one of them was fully anticipated by Bacon; that he clearly

saw all its weaknesses and defects; and that he enforced his insight by constant, bold, vigorous and searching criticism. If we analyze the scientific methods of Galileo, Huyghens and Newton we shall find that, in their large lines, they are the same as those of the Experimental Science based upon mathematics, of which Bacon was the first inventor and almost the only exponent for three hundred years

The thirteenth century, as a whole, received its full expression in the works of Albertus Magnus. We can only comprehend the admirable independence and originality of Bacon's mind when we have compared him, point by point, with his great rival. They are literally worlds apart. One epitomizes the old world; the other foretells the new. Seen in this summary way Bacon appears a *lusus naturæ*—as a man born quite out of his own time; and he is usually so regarded. When, however, we consider his whole career with a minuteness that has been impossible in this short sketch, we discover that the seeds of the rich harvest of his mind were sown by his great teacher, Robert of Lincoln; that in Paris Peter of Mericourt—the author of *De Magnete,* from which Gilbert of Colchester derived many of his ideas —was his master in experimental science; and that both in Oxford and Paris he found many kindred spirits. We have proofs, therefore, that in the first half of the thirteenth century there were at least two companies of open-minded and liberal scholars. The fame of Bacon's lectures at the universities testifies to the existence of the same spirit in other large companies. It is only because the annals of the time are so deficient, and especially because the history of that time has been written by the Dominicans, his enemies, that we cannot adduce other specific instances, with names and dates, to demonstrate more fully that Bacon had the fellowship of men of his own stamp; that, in a strict sense he was the highest product of his age; that he was not, at least for half his life, utterly isolated. Until we understand these conditions we cannot comprehend his true relations to his age. At the beginning of the century there was a striving towards sound learning—a veritable revival—of which Bacon is the highest exponent. We are not concerned to here exhibit how and why the spirit of the century changed when its years were half run out.

If his career could have been, like that of Albertus Magnus, molded into a reasonable conformity to the spirit of his time, his works would have also been the text-books of the schools of the thirteenth century; his influence would have been immense and immediate; the revival of learning would have dated from Bacon, not from Petrarch; the foundations of modern science would have been firmly laid three centuries before Copernicus. Why these changes were not to be is explained by his character: and his character was his fate.

LAMARCK, THE FOUNDER OF EVOLUTION.*

BY PROFESSOR W. H. DALL.

IT is now nearly a century since Lamarck published the outlines of his theory of evolution by descent with modifications transmitted by heredity and initiated by dynamic impulses; originating in the mass of animals from the environment, and in the higher and more intelligent groups partly from within the developing organism itself.

Met by the ridicule and unfriendly criticisms of the 'creationists,' which were the more generally accepted on account of the modesty, retiring disposition and aversion to controversy of Lamarck himself, handicapped by the blindness and poverty of his later years, his views have been little known in their true shape, and the majority of naturalists have been content to receive them in the garbled form in which they were presented by those who rejected them. Theoretical, as the conditions of science at the time made obligatory; in some respects with our present light obviously erroneous; the philosophy of Lamarck nevertheless contained also a body of opinion substantially in harmony with the evolutionary ideas of Spencer and Darwin, and which has been established by the work of modern students of nature, among the axioms of science.

It was then a pious task which Professor Packard undertook, to present in its true form the zoological philosophy of this venerable pioneer, that the present generation of philosophers might learn their obligations to him. To this sympathetic exposition of Lamarck's views the author has prefixed a summary of the meager details in regard to his private life and public services, which a careful search has been able to discover; illustrated them by pictures of the house in which Lamarck was born, and that in which most of his work was done and where he died, adding a facsimile from his manuscript. Finally a chapter has been added in which the revival of Lamarckian ideas among an influential body of modern students is summarized.

Jean-Baptiste-Pierre-Antoine de Monet, Chevalier de Lamarck was born August 1, 1744, at Bazentin-le-Petit, Department of the Somme, near Longueval. His mother was Marie Françoise de Fontaine. His family belonged to an ancient race of the minor nobility of Béarn. On the death of his father in 1760, he joined the French army, then campaigning in Germany. Almost immediately afterward he achieved

* Lamarck, the founder of evolution, his life and work, by Alpheus S. Packard, M.D., LL.D. Longmans Green and Co., New York, 1901. Pp. xiv + 451, 8°, ills.

distinction and was named an officer on the field, for especially gallant conduct at the battle of Fissinghausen in Westphalia. He soon became a lieutenant but an injury inflicted by a brother officer at play obliged him to retire to Paris for surgical aid and to leave the army. He attempted to study medicine, served as clerk in a bank and made himself acquainted with botany to which finally he gave his whole attention under Bernard de Jussieu for some ten years, when he published his 'Flore Française' which gave him at once a national reputation. Through the influence of Buffon he obtained a post in the Academy of Sciences, and, as companion to Buffon's son, traveled on the continent in Germany, Hungary and Holland, visiting museums and making botanical collections. After his return Buffon's successor appointed him keeper of the herbarium in the Royal Botanical Garden with a stipend of 1,000 francs, which was later raised to 1,800 francs. In 1793 the establishment was reorganized as the Museum of Natural History and in the midst of the revolution, under the new conditions the botanist Lamarck was appointed to a professorship of zoology, in charge of the collection of invertebrate animals, the other zoological professorship, involving the care of the vertebrate collections being assigned to Etienne Geoffroy St. Hilaire, a devoted friend of Lamarck and like him an evolutionist. Lamarck, now fifty years old, married a second time, with six children, received a suite of rooms in the Maison de Buffon attached to the garden, and a salary of 2,868 livres. Here he remained, lectured and worked, until blindness overtook him about 1821, when the last volume of the Animaux sans Vertébres prepared from his dictation by his devoted daughter, Cornélie, was presented to the assembly of professors attached to the establishment. He died in the Maison de Buffon, December 28, 1829, and was buried in a temporary grave in the cemetery of Mont Parnasse. His bones, mingled with those of a thousand others, lie somewhere in the catacombs of Paris. To the adversities suffered in life was added the delegation by the academy of the preparation of his memorial *éloge* to Cuvier, his most determined opponent in the ranks of the 'creationists.' While destitute of low malice this memoir, conceived in a spirit of contempt for Lamarck's philosophical theories, has done much to obscure his merits and place him in a false light before posterity. That the present volume may vindicate his reputation and lead to a more impartial estimate of the work of this truly great naturalist and admirable man, may confidently be predicted; as even those who differ from Lamarck's conception of environmental and dynamic factors in evolution must feel obliged to recognize much in other phases of his philosophy which now forms the common property of science, but which Lamarck was among the first to advance and which he maintained steadily, in spite of ridicule and incredulity, to the end of his days.

COMETS' TAILS, THE CORONA AND THE AURORA BOREALIS.

By Professor JOHN COX,

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THERE is undeniable fascination about a theory which includes within its sweep the time-honored problems of astronomy connected with comets' tails and the reason why they point away from the sun; the solar prominences and the corona; the source of the light by which the nebulæ shine; the origin and structure of meteor-swarms; and the aurora borealis; besides solving incidentally half a dozen minor outstanding mysteries of the heavens.

Such a theory has been advanced by Sweden's distinguished chemist and physicist, Svante Arrhenius, in a paper published in the 'Physikalische Zeitschrift' for November, 1900. Its main points were briefly mentioned with approval by no less an authority than Professor J. J. Thomson at the end of his captivating article on 'Bodies smaller than Atoms' in the August number of The Popular Science Monthly. All the physical principles on which Arrhenius relies, with one exception, are explained at length in that article, and are now very generally accepted. We may therefore say that the theory is based on 'veræ causæ,' and its accordance with known facts is so impressive when the comparison is made in detail that I venture to think the readers of Professor Thomson's article will be interested in a more complete statement of Arrhenius' views than time permitted him to give.

Let us begin by taking stock of the physical principles already to hand. We know (Professor Thomson's paper) that corpuscles, about 1,000 times smaller than hydrogen atoms, and each bearing a charge of negative electricity, are discharged with high velocity:

(1) from the negative electrode in a Crookes tube (kathode rays).
(2) from objects struck by kathode rays (Röntgen rays).
(3) from hot bodies, such as glowing metals.
(4) from cold metals under the influence of ultra-violet light.
(5) from the radio-active substance radium.

Again we know that these corpuscles, or *ions,* in passing through a gas produce other ions by collision with the molecules of the gas, and that the negatively charged ions are capable of serving as nuclei for the condensation of ordinary matter.

Comets' Tails.

The single new principle introduced by Arrhenius arises in connection with the problem of comets' tails. Astronomers have always felt that the phenomena exhibited by these strange objects could only be accounted for by making the sun the seat of a violent radial repulsive force, but were entirely at a loss to account for this repulsion. So long as light was supposed to consist of myriads of corpuscles discharged with a speed of 186,000 miles per second, it was easy, with Kepler, to regard the corpuscles as carrying with them in their rush the materials vaporized from the comet by the heat of the sun. But the establishment of the Wave-Theory of light put an end to this idea. Thus Newcomb says ('Popular Astronomy'): "If light were an emission of material particles, as Newton supposed it to be, this view would have some plausibility. But light is now conceived to consist of vibrations in an ethereal medium; and there is no known way in which they could exert any propelling force on matter!"

Now Arrhenius points out that according to the Electromagnetic Theory of light a ray of light *does* exert a pressure on any surface on which it impinges. Maxwell not only proved this in his original publication of the theory in 1873, but showed how to calculate its value. With the known constants of solar radiation he found that sunlight at the surface of the earth should exert a pressure of $.592 \times 10^{-10}$ grams on every square centimeter. This is too small a force to be detected, though it has been looked for.

But at the surface of the sun the pressure would mount up to 2.75 milligrams per sq. cm. On the other hand, a cubic centimeter of water, which weighs one gram at the surface of the earth, would weigh 27.47 grams at the surface of the sun, *i. e.*, the attraction of the sun would draw it inwards with about 10,000 times the force with which the sun's light would tend to drive it away.

Very different is the case if, instead of a cubic centimeter, we consider a much smaller cube. The pressure on its base would fall off as the square of its edge, but the weight would diminish as the cube. There must come a point at which the pressure of the light would just balance the weight; and still smaller particles would be driven off with a force greater than their weight. *They would behave, in fact, as if gravity had become negative.*

For example, a cube of water measuring one-thousandth of a millimeter (10^{-4} cm.) in the edge would weigh 27.47×10^{-12} gms.; and the pressure of light on its base would be $2.75 \times 10^{-3} \times 10^{-8}$, $= 27.5 \times 10^{-12}$ gms., *i. e.*, slightly more than its weight.

In measuring wave-lengths of light physicists denote one-thousandth of a millimeter by the symbol μ. The critical value of the edge of a cube of water, *i. e.*, the value for which its weight is exactly neutralized

by the pressure of light at the sun's surface, is thus approximately μ. For a spherical drop the critical diameter may be calculated to be 1.5 μ for water. For other substances the critical value is inversely proportional to the specific gravity.

A similar effect of extreme minuteness is familiar to us as the explanation of the long time required by very small particles to settle through the atmosphere, amounting to many months in the case of the finely divided dust thrown up during the eruptions of Krakatoa. But the resistance to suspended dust particles can never exceed their weight, since it is only called forth by the motion produced by the weight itself. The pressure of light now considered may enormously exceed the weight provided the particles are small enough.

From the motions, and especially the curvature, of comets' tails the magnitude of the repulsive forces to which they are subject may be calculated. Thus Bredichin finds, in four instances, that the repulsion must have been about 18.5, 3.2, 2.0, and 1.5 times the sun's gravitational attraction. Now the vapors emitted by comets are largely hydrocarbons of specific gravity about .8. To account for these repulsions on Arrhenius' principle, the drops must have had diameters of 0.1 μ, 0.59 μ, 0.94 μ, 1.25 μ respectively. In another case, where the tail curved towards the sun, Bredichin found the repulsion to be 0.3 times gravity. This would indicate particles of diameter 6 μ. Particles of this order of magnitude, and far smaller, are familiar enough to us, especially in combustion and in the early stages of condensation.

The theory suggested is then as follows: As the comet approaches the sun, the intense heat causes a violent eruption of hydrocarbon vapors on the side towards the sun. The hydrogen boils off, and the vapors condense into small drops of hydrocarbons with higher boiling-points, or ultimately solid carbon is thrown out, finely divided as in an ordinary flame. The largest of these particles fall back to the comet, or if they are not condensed till at a great distance from it, they form tails turned towards the sun. The smaller are driven rapidly from the sun by the pressure of its light, with a speed depending on their size, and form the ordinary tails pointing away from it. That particles of different sizes should be formed from the same comet is natural since the comet is likely to be formed of heterogeneous materials, and there must be great variety in the circumstances of condensation. Thus the comet of 1744 had no less than five tails of different curvature. Occasionally the calculated repulsion on the same tail is not found to follow exactly the law of the inverse square of the distance from the sun throughout its whole length. This puzzling circumstance is at once explained, if the particles should for any reason change their state of aggregation, and consequently their size, during their headlong career. In the light of this theory the following passages will be found very suggestive.

(Herschel, 'Outlines of Astronomy,' p. 376.)

"It is for the most part after thus passing the sun, that they shine forth in all their splendor, and that their tails acquire their greatest length and development; thus indicating plainly the action of the sun's rays as the exciting cause of that extraordinary emanation."

Again (p. 566).

"The tail of the great comet of 1680 immediately after its perihelion passage was found by Newton to have been no less than 20,000,000 leagues in length, and to have occupied only two days in its emission from the comet's body! a decisive proof this of its being darted forth by some active force, the origin of which, to judge by the direction of the tail, must be sought in the sun itself."

Now a particle with one-half the critical diameter would in the course of traveling from the sun's surface to a distance equal to his radius acquire a speed of 430 kilometers per second. With this velocity it would cross a space equal to the diameter of the sun, 865,000 miles, in less than an hour. In comets' tails we probably have to do with particles having less than one eighteenth of the critical diameter. Such particles would cover the same distance in less than four minutes. With a force many times the sun's attraction driving them into space, they would make little of 20,000,000 leagues in two days; whereas if this were to be accomplished against gravity the velocity of projection required might well stagger the astronomers.

Referring to Halley's comet, Herschel says (p. 381):

On the 2d of October (*the very day of the first observed commencement of the tail*) the nucleus, which had been faint and small, was observed suddenly to have become much brighter, and to be in the act of throwing out a jet or stream of light from its anterior part, or that turned *towards* the sun. This ejection after ceasing a while was resumed, and with much greater apparent violence, on the 8th, and continued with occasional intermittences so long as the tail itself continued visible. . . These jets, though very bright at their point of emanation from the nucleus, faded rapidly away, and became diffused as they expanded into the coma, at the same time curving backwards, as streams of steam or smoke would do, if thrown out from narrow orifices, more or less obliquely, in opposition to a powerful wind, against which they were unable to make way, and ultimately yielding to its force, so as to be drifted back and confounded in a vaporous train, following the general direction of the current.

It seems impossible to avoid the following conclusions. 1st. That the matter of the nucleus of a comet is powerfully excited and dilated into a vaporous state by the action of the sun's rays, escaping in streams and jets at those points of the surface which oppose the least resistance. 2ndly. That this process chiefly takes place in that portion of the nucleus which is turned towards the sun; the vapour escaping chiefly in that direction. 3rdly. That when so emitted, it is prevented from proceeding in the direction originally impressed on it, by some force directed *from* the sun, drifting it back and carrying it out to vast distances behind the nucleus, forming the tail. 4thly. That this force, whatever its nature, *acts unequally* on the materials of the

comet. 5thly. That the force thus acting on the materials of the tail cannot possibly be identical with the ordinary gravitation of matter, being centrifugal or repulsive, as respects the sun, and of an energy very far exceeding the gravitating force towards that luminary. This will be evident if we consider the enormous velocity with which the matter of the tail is carried backwards, in opposition both to the motion which it had as part of the nucleus, and to that which it acquired in the act of emission.

Again, describing the long straight tail of the great comet of 1843, from which a lateral tail, nearly twice the length of the regular one, was shot forth in a single day, Herschel says:

The projection of this ray, which was not seen either before or after the day in question, to so enormous a length (nearly 100°) in a single day conveys an impression of the intensity of the forces acting to produce such a velocity of material transfer through space, such as no other natural phenomenon is capable of exciting. It is clear that *if we have to deal here with matter, such as we conceive it, viz., possessing inertia, at all,* it must be under the dominion of forces incomparably more energetic than gravitation, and quite of a different nature.

And finally (p. 406):

There is beyond question some profound secret and mystery of nature concerned in the phenomenon of their tails. In no respect is the question as to the materiality of the tail more forcibly pressed on us for consideration than in that of the enormous sweep which it makes round the sun in perihelio, in the manner of a straight and rigid rod, in defiance of the law of gravitation, nay, even of the received laws of motion, extending (as we have seen in the comets of 1680 and 1843) from near the sun's surface to the earth's orbit, yet whirled round unbroken, in the latter case through an angle of 180° in little more than two hours. It seems utterly incredible that in such a case it is one and the same material object which is thus brandished. If there could be conceived such a thing as *a negative shadow,* a momentary impression made upon the luminiferous ether behind the comet, this would represent in some degree the conception such a phenomenon irresistibly calls up. But this is not all. Even such an extraordinary excitement of the ether, conceive it as we will, will afford no account of the projection of lateral streamers; of the effusion of light from the nucleus of a comet towards the sun; and of its subsequent rejection; of the irregular and capricious mode in which that effusion has been seen to take place.

These passages give a vivid picture of the utter puzzledom of astronomers over difficulties which arise from precisely those phenomena which fit most naturally into the theory of Arrhenius.

The Prominences and the Corona.

At the moment when the sun's disc is obscured in a total eclipse enormous red flames, sometimes curving over towards the sun and sometimes floating like clouds at heights up to 40,000 miles above his surface, are seen projecting over the region of sunspots, where the sun's eruptive activity is greatest; and silvery streamers with a radial structure form a lens-shaped envelope about the same region, often extending

to a distance of several times the sun's radius. These are known as the prominences and the corona.

The sun must itself project vapors into space. When these condense, the drops will, if larger than the critical size, fall back to the sun, giving rise to the curved prominences; and if smaller, they will be driven off into space, and be seen as the streamers of the corona. Since the eruptions will not always be perpendicular to the sun's surface, the prominences will often exhibit parabolic curves, and the streamers may not always be strictly radial, though the greater part of this effect is to be attributed to the foreshortening under which some of them are viewed from the earth.

Those particles which have approximately the critical diameter will float as clouds, sustained by *the pressure of light.* This point is specially interesting, since it has been difficult to account for the maintenance of the cloudlike prominences without assuming the existence of a considerable atmosphere about the sun. Yet the comet of 1843 described 300,000 miles within a distance of less than one-third of the sun's radius from his surface with a velocity of 350 miles per second, and came out without having suffered any visible damage or retardation.

The corona has been as great a stumbling-block to astronomers as the comet's tail. Thus Newcomb ('Popular Astronomy,' p. 263) says:

> The corona is not a mass of foggy or milky light, but has a *hairy structure* like long tufts of flax. . . Of this appendage we may say with confidence that it cannot be an atmosphere, that is, a continuous mass of elastic gas held up by its own elasticity. . . What then is the corona? Probably detached particles partially or wholly vaporized by the intense heat to which they are exposed. . . The difficult question which we meet is, How are these particles held up? To this question only conjectural replies can be given.

Three conjectures are then mentioned, of which we may note the first.

> That the matter of the corona is in what we may call a state of projection, being constantly thrown up by the sun, while each particle thus projected falls down again according to the law of gravitation. The difficulty we encounter here is that we must suppose velocities of projection rising as high as 200 miles per second constantly maintained in every region of the solar globe.
>
> The prominences are of two classes—the cloud-like and the eruptive. The first class presents the appearance of clouds floating in an atmosphere; but as no atmosphere dense enough to sustain anything can possibly exist there, we find the same difficulty in accounting for them, that we do in accounting for the suspension of the matter of the corona.

Professor Young is frankly despairing.

> I do not know what to make of the corona. . . By what forces the peculiar radiated structure of the corona is determined I have no definite idea. The analogies of *comets' tails and auroral streamers* both appear suggestive; but on the other hand, the spectra of the corona, the aurora borealis, the comets and the nebulæ are all different, no two in the least alike. . . Nor

have I any theory to propose to account for *the certain connection between disturbances of the solar surface and of terrestrial magnetism.*

The words we have underlined in this passage have almost a Sophoclean irony to a reader acquainted with the further developments of Arrhenius' theory to which we now turn.

The Zodiacal Light and the Gegenschein.

Not only is the sun the source of those eruptions of ordinary matter which form the prominences, but we have every reason to be believe that he must emit streams of electrically charged corpuscles both directly, as a hot body, and indirectly, since the electrical discharges which, according to all terrestrial analogies, must accompany the violent chemical actions going on near his surface, will, when they take place in the higher and rarer regions of his atmosphere, give rise to kathode rays, and these, in turn, to Röntgen rays. As Professor Thomson says: "As a very hot metal emits these corpuscles, it does not seem an improbable hypothesis that they are emitted by that very hot body, the sun."

Now the negatively charged corpuscles are preeminently fitted to serve as nuclei for the condensation of the ordinary matter. Hence those particles of the latter which, having more than the critical diameter, fall back to the sun, will carry back a negative charge to him; while those which have less than the critical diameter will carry a negative charge off into space. On both counts the corona will be left with a surplus of positive charge. The same arguments hold for the vapors emitted by the nucleus of a comet. Thus comets' tails should consist of negatively charged particles.

Let us follow the career of the particles launched into space. They proceed radially from the sun above the regions of sunspots with rapidly increasing speed, which, however, may be shown to approach a finite limit at a distance of about ten radii from the sun. If they encounter another body, such as the earth, they charge its outer atmosphere negatively, and when this charge reaches a certain value, it will begin to repel them. The oncoming rush will be deflected, and stream past the earth on each side in hyperbolic orbits. Far out in space they must sooner or later meet particles from other bodies, and, if by collision or aggregation they increase beyond the critical diameter, they will first lose speed and then drift back with ever increasing velocity past the earth, directly towards the sun. The space immediately behind the earth would be screened by her, and so be void of particles. Could we take our stand on the moon, we should thus see the earth attended by a faint double tail with a dark dividing line (so conspicuous a feature in comets), immediately behind it, pointing from the sun; and a similar, though perhaps fainter, tail, pointing towards him. Not only so, but the earth helps to form her own tail. For when

the negative charge in the upper atmosphere is high enough, discharges are brought about by the powerful ultra-violet radiation from the sun, and particles are driven off radially from the earth on the side turned towards the sun, only to be drifted back with the other streams into the tail. The effect will be as if a sheaf of light projected from her towards the sun.

Compare with this the description of the Zodiacal Light (Newcomb, 'Popular Astronomy,' p. 416):

> This object consists of a very soft faint column of light, which may be seen rising from the western horizon after twilight on any clear winter or spring evening; it may also be seen rising from the eastern horizon just before daybreak in the summer or autumn. It really extends out on each side of the sun, and lies nearly in the plane of the ecliptic. . . Near the equator, where the ecliptic always rises high above the horizon, the light can be seen about equally well all the year round. . . It is due to a lens-shaped appendage of some sort surrounding the sun, and extending out a little beyond the earth's orbit.
>
> The nature of the substance from which this light emanates is entirely unknown. . . Professor Wright of Yale College finds its spectrum to be continuous. Accepting this, we should be led to the conclusion that the phenomenon in question is due to reflected sunlight, probably from an *immense cloud of meteorites*, filling up the space between the earth and the sun.

The difficulty in this view is that the orbits of such swarms of meteorites as are known to us are distributed irregularly with regard to the ecliptic. On the other hand, Arrhenius' streams of particles, when near enough to be visible, necessarily lie in or near the ecliptic, as required by observation. More than this, the particles emitted by the earth herself should be most abundant over those regions which have been exposed for many hours to the sun. Now it has been observed that the zodiacal light is stronger on what Arrhenius calls the 'evening side' of the earth (*i. e.*, that side which is in the act of turning away from the sun, and has the sun in the west) than on the 'morning side.'

Even at night, when the sun is below the horizon, faint reflections should reach us from the streamers behind the earth, and by an effect of perspective, these should have a maximum in the *point opposite to the sun*, where they will appear most dense. Let Professor Newcomb describe the Gegenschein:

> Another mysterious phenomenon associated with the zodiacal light is known by its German appellation, the Gegenschein. It is said that in that point of the heavens directly opposite the sun there is an elliptical patch of light, a few degrees in extent, of such extreme faintness that it can be seen only by the most sensitive eyes, under the best conditions, and through the clearest atmosphere. This phenomenon seems so difficult to account for that its existence is sometimes doubted; yet the testimony in its favor is difficult to set aside.

How is it that the moon does not exhibit such tails? The moon has

no atmosphere, so that the particles which reach her give up their negative charge to her directly, and it spreads equally all over her surface. When in turn she herself discharges the particles, it will be uniformly in all directions, and she should appear surrounded with a uniform sheath. Possibly this sheath of cosmical dust affords the reason that in a lunar eclipse the shadow of the earth can be traced a short distance beyond the limb of the moon on each side.

The Aurora Borealis.

Perhaps the most interesting application of Arrhenius' theory is his explanation of the Aurora. In a well-known experiment the streams of negative particles forming kathode rays in a Crookes tube are exposed to a magnetic field, when they are seen to describe helices round the lines of force. If the field is powerful enough, they may thus be bent into a complete circle inside a moderately large tube.

Now the negative particles discharged from the sun arrive most thickly over the equatorial regions of the earth, which are most directly exposed to him. Long before they reach any atmosphere dense enough to excite luminescence, they are caught by the lines of force of the earth's magnetic field, which are horizontal over the equator, and have to follow them, winding round them in helices whose radii are so much less than their height above us that the effect to a beholder on the earth is as if they moved *along* the lines of force. Over the equator there is little luminescence, for lack of atmosphere. But as the lines of force travel north and south, they dip downwards making for the magnetic poles, over which they stand vertical. Soon the particles find themselves in lower layers of the atmosphere, comparable in density with our highest artificial vacua, and begin to give out the darting and shifting lights of the kathode ray. But this can only be at the cost of absorption, and by the time the denser layers of air are reached, their energy is exhausted. Hence the dark circles round the magnetic poles from which, as from behind a curtain, the leaping pillars of the Aurora rise. From this point of view it is significant that Dr. Adam Paulsen, who has made a special study of the northern lights, found so many points of correspondence between them and kathode rays that in 1894 he was led to regard the aurora as a special case of the latter, though unable to give any account of their origin in the upper atmosphere, such as is supplied by Arrhenius' theory.

The most obvious test to which we can subject such a theory is to ask from it some explanation of the very remarkable periodic variations in the frequency of auroræ. If they are caused by streams of particles ejected from the sun, there should be some connection between the changes in the sun's activity, as indicated by the number of sunspots, and the number of auroræ observed. Again, since a negative charge

in motion is (pace M. Cremieux) equivalent to a negative current, the passage of electrified particles through the upper atmosphere should affect magnetic instruments on the earth. Sunspots, auroræ, magnetic storms should therefore vary together.

It has long been known empirically that they do agree in a general way. Arrhenius' discussion of the mass of statistics of observed auroræ forms so striking an example of the 'Method of Concomitant Variations' that at the risk of wearying the reader we shall give it in some detail.

1. *Slow secular periods.*

(a) Both sunspots and auroræ show marked maxima at the middle of the eighteenth and the end of the nineteenth centuries.

(b) Sunspots, auroræ, and magnetic storms go through a simultaneous increase and decrease in the well-known period of 11.1 years.

The source of these slow variations must be looked for in the little understood variations of the sun's activity.

2. *Annual period.*

The number of auroræ is greatest in March and September, and least in June and December; and the mean frequency for both hemispheres is somewhat less in June than in December.

Now the sun's activity, as indicated by the number of sunspots, is a minimum at his equator, the spots occurring principally in belts about 15° north and south of his equator. Since the streams of particles issue radially from the sun, the earth will be most exposed to them, when she is most nearly opposite the active belts. But the earth stands opposite the sun's equator on June 4 and December 6, and is at her farthest north and south of it (7°), *i. e.*, most nearly opposite the sunspot belts, on March 5 and on September 3. Moreover, she is somewhat nearer to the sun in December than in June.

As between the two hemispheres, the same conditions apply as those which regulate the seasons, viz., altitude of the sun above the horizon, and length of time during which he remains above it daily. Auroræ should therefore be more frequent in summer than in winter, a result which is verified by the records. And just as the highest daily temperature occurs from two to three hours after mid-day, so we ought to find a daily maximum of auroræ about 3 p. m. It is not possible to verify this directly, since auroræ are not visible in daylight. But Arrhenius remarks (1) that the majority of them occur before midnight and not after it, which is so far in general agreement with the theory; (2) that Carlheim-Gyllenskiöld, discussing the observations made at Cape Thordsen in Spitzbergen during the winter of 1882–1883, with a view to correcting the numbers recorded for the effect of daylight in concealing them, deduces a probable maximum for the number actually occurring at 2.40 p. m.

But though we cannot observe auroræ in daylight, we are not without resource, for even when invisible, they give notice of their presence by disturbing the ordinary course of the records photographically taken in our magnetic observatories. In 1899 van Bemmelen discussed the records of such magnetic storms taken in Batavia. He found that they show maxima in March and September, minima in January and June, and a daily maximum at 3 p. m., and minimum at 1 a. m.

3. *Monthly Variations.*

It is only recently (1898) that the collection of statistics of auroræ published by Eckholm and Arrhenius has brought to light two curious monthly variations in their number.

One of these, with a variation of 20% on each side of the mean, depends on the revolution of the moon in her orbit, showing in the northern hemisphere a maximum when the moon is farthest south of the equator, a minimum when she is farthest north; and vice versa for the southern hemisphere.

The explanation appears highly ingenious. It is as follows: The moon, being unprotected by an atmosphere, is charged by the streams of particles that reach her much as the outer layers of our own atmosphere are charged, and therefore, as we have good reason to believe, to a far higher negative potential than is observed at the surface of the earth. If so, she will seriously affect the number of auroræ at any place over which she stands, by lowering the potential gradient, and thus reducing the number of negative discharges in the highest regions of our atmosphere.

The other variation of some 10% each way has a period of 25.93 days and affects both hemispheres alike. At first sight it is natural to refer this to the synodical time of revolution of the sun on his axis as determined by observations of sunspots. But this is 27.3 days. Remembering that the earth never departs more than 7° from the sun's equator, we should rather take the time of revolution of the equatorial belt for comparison. As estimated by the motion of the faculæ, this is 26.06 days, the equator moving faster than the sunspot belts, and probably the time of revolution of the outermost layers, from which the particles stream, is yet a little shorter. The agreement with the period of the aurora (25.93 days) would thus be within the limits of error of the observations.

Atmospheric Electricity.

Let us now trace the effect of the auroræ on the earth's atmosphere. If they are really kathode rays on a grand scale, they must ionize the air, the negative ions will form centers for condensation, and sinking to the earth by gravitation, will charge it negatively, leaving the layers

at moderate heights positively charged. This agrees with the results of recent observations made from balloons up to heights of 3,000 meters.

Since condensation will depend on the number of ions available for nuclei, we have at once an explanation of the curious fact that cloud-formation in the upper atmosphere is more copious in years of frequent auroræ than when they occur rarely. In this connection another odd coincidence may be mentioned. When sunspots are numerous, Jupiter shines with a white light; when they are few, his light has a reddish tinge. Now it is agreed that Jupiter is still at a high temperature. If, therefore, sunspots cause auroræ on Jupiter, and consequent cloud-formation, we must see less of the heated interior in sunspot years than we do when his cloud-layers are not so opaque.

In 1899 von Bezold showed that the daily variation of the compass over the earth's surface could be simply represented as follows. Imagine two points, one in latitude 40° N., and one 40° S., to move round with the sun. Then it is as if the north end of the compass needle were attracted towards the northerly point, and the south end towards the southerly. Remembering that the air immediately above the earth has a positive charge, we see that this effect would follow by Ampère's rule, if the sun's heat caused two air-whirls, one in the northern and one in the southern hemisphere, over the places of highest temperature, the former rotating counter-clockwise, the latter clockwise. Such whirls would result from the sucking in of currents from the slower-moving north latitudes and the faster-moving south latitudes towards the mean latitude of 40°, in the northern hemisphere, and similarly for the southern. If this be the true explanation, then for a given frequency of sunspots, the amplitude of the diurnal variation should increase by the same fraction of itself for all parts of the earth. Thus if A° is the amplitude at a given place in a year of no sunspots, and A its value in a year for which Wolf's number expressing the relative frequency of spots is f, we ought to find $A = A^\circ\ (1+af)$. Now the value of the coefficient a comes out .0064 from *whatever part of the world* the observations be taken from which it is calculated.

Meteorites and Nebulæ.

To the man of science this discussion of terrestrial details will probably be the most convincing part of the evidence adduced by Arrhenius for his theory. But it is time to turn from it, and follow, with lagging imagination, the destinies of those particles, by far the greatest number, which miss the earth and the planets, and launch forth into interstellar space.

Many of them will meet similar streams ejected from other suns,

and overcoming the mutual repulsion of their negative charges by their mighty velocities, will clash together, like Lucretius' atoms, and unite to form larger masses. But this aggregation must have an end. For if, in the void of space, they are unable to get rid of their electric charges, the potential of the growing mass must rapidly increase, since the charge increases as the cube of the radius, being proportional to the total number of particles, while the capacity for holding electricity only increases as the radius itself. To put this in popular language, each particle brings to the account the whole charge it can bear on its surface; but in the mass, since electricity flies to the surface, only the outer parts of those particles which are actually in the surface can be useful in harboring the accumulating charge, and hence the electric pressure rises. When it becomes intense enough to prevent fresh particles from approaching, accretion will cease. Space will thus be sown with masses of moderate size, formed irregularly, particle by particle, in spite of repulsive forces. These are the meteorites which blaze for a moment in the upper air, or in rare cases reach the earth to puzzle philosophers with their porous structure.

Another multitude of the particles will at last reach other suns. For if in their wanderings they have united with others till they are beyond the critical size, they will be drawn in, and raise the charge of the bodies they reach, till they in turn discharge their streams into space.

In these we see the 'greyhounds' of the abyss, engaged in distributing the materials of the universe, forever busied in a cosmic traffic by whose exchanges the stellar hosts are made more and more alike in constitution, whatever may have been their differences in the beginning.

For those myriads which are fated to escape all visible suns, far out in the 'flaming bounds of space' the Nebulæ lie in wait, spreading spider-like their impalpable webs across immeasurable breadths of sky. Ever since the spectroscope showed that many nebulæ are gaseous, and yet shine by their own light, two problems have vexed the astronomers. How can they be hot enough to send light to us, and yet be held together against the expansive force of the heated gas, by the feeble gravitation which such inconceivably diffuse masses can exert at their borders? If they are really at a temperature of not less than 500° C., so as to shine, or, indeed, if they are much above absolute zero, their own gravitation should not be able to prevent their speedy dissipation into space.

Again, why do they show the spectroscopic lines of so few gases, and those the lighter ones, such as hydrogen and helium?

According to Arrhenius the nebulæ are cold, with the cold of empty space. Their light is due to the rain of negatively charged

particles which, plunging into their outermost regions, give rise to electric discharges and make their gases shine as the gases in a vacuum tube. To this the intense cold is no bar, for Stark has shown that the intensity of light excited in a vacuum tube is greater the lower the temperature at which the experiment is tried. And this process should take place at the surface of the nebula, where the lighter gases would be found, the heavier settling inwards. Hence the few lines found in the spectrum of a nebula, and the comparative brightness of the outlying parts, especially to be observed in the planetary and the ring nebulæ.

Such is Arrhenius' theory. It is too early, as yet, to pronounce any judgment upon it, but glancing back over the array of hitherto unexplained facts which fall into order, without forcing, at its touch, we must admit that it is at least plausible. It springs from a single principle, itself a necessary theoretical consequence of the accepted Electromagnetic Theory of light, viz., that light must exert a pressure which, in the case of small particles, may very greatly exceed their weight. By means of this principle in conjunction with recent views about the nature and properties of ions, which can all be experimentally verified, this theory gives a rational explanation of the astounding behavior of comets' tails; accounts for the 'hairy' structure of the corona; shows us how the prominences can float where the existence of a supporting atmosphere is inadmissible; what is the origin of the zodiacal light and the Gegenschein; of 'the certain connection' between sunspots and magnetic storms; of the aurora, and why it is subject to such complicated periodical variations; why meteorites are porous and limited in size; how the nebulæ shine in the absolute cold of interstellar space, and yet hang together; and why their constituents appear to be so restricted, while the suns among which they are strewn give evidence of most of the elements known on earth.

A theory which sweeps the astronomical horizon of so many mysteries must not only arouse our profound interest, but claim the respectful consideration of men of science.

DISCUSSION AND CORRESPONDENCE.

THE NOACHIAN DELUGE.

To the Editor:—My attention has just been called to the inquiries in the August number of the MONTHLY concerning the reply I would make to a number of objections which arise in connection with my theory of the Noachian Deluge. As they are apparently made in good faith I will briefly remark upon them, though it would require a volume fully to discuss the points raised.

1. The question respecting Noah's supposed relation to paleolithic man is answered by saying that it is by no means proved that paleolithic man in Europe and America was not cotemporary with civilized man in Egypt and Babylonia, whose existence is now thrown back in those countries several thousand years before the Christian era. I do not know that there is any evidence that paleolithic man anywhere developed into neolithic man, and so on to a stage of comparative civilization by his own efforts. It seems more likely that he received his new arts by contact with higher races than that he made the inventions of his own accord. Certainly, in America, he did not pass out of the 'stone age,' by himself.

2. With regard to the age of Noah as given in the Scriptures when his surviving children were born it is enough to say that language, like isolated geological facts, has to be interpreted; and it is a fair question whether Noah, here, is not the name of a dynasty, like Pharaoh, or of a family, like Israel. That is to be determined by a thorough study of the literature involved. Israel is indeed the name of a man, but it is constantly used to designate the whole body of his descendants. In so brief an account of a long period of history as we have in the early chapters of Genesis, it would not be strange if much more was compressed into single words than would be done in a fuller history.

3. In reference to the specific statement of facts, it is proper to remark that outside of mathematical and dry scientific treatises, there is little specific statement of facts by anybody. When I read in the papers that the whole town turned out to witness a pageant, I do not expect on inquiry to find that there were no women and children or busy or indifferent men absent, nor do I charge the writer with misrepresenting the facts in making the general statement. But, on the other hand, I take the nature of language into consideration and interpret it to mean simply that there was a great crowd, which had the *appearance* of containing everybody in the town. Again, when I read in a scientific treatise, as I frequently do, that a fact, or explanation of a fact, is 'generally' admitted, I do not charge the writer with either dishonesty or ignorance if it is found that nine tenths of the people of the world have heard neither of the fact nor of the explanation, nor yet if it is found that both the alleged fact and its explanation is disbelieved by a considerable portion of the civilized world. There are few questions on which there is perfect unanimity of judgment, hence if we use the word 'generally' at all, outside of mathematics, we must use it in a modified sense and leave the interpretation to the context.

Applying this well-known principle of interpretation to the case in hand, it is possible to get a pretty definite

conception out of the language both of the Bible and of other confirmatory traditions without being pressed to accept it with mathematical exactness. The single point which I have made is, that, in view of the great instability of geological conditions which accompanied the close of the glacial period, and during which man was in existence, it is unscientific to apply to that period the standards with reference to the rate of elevation and depression of the earth's surface which apply to the present. I have also called attention anew to the unknown, but certainly extensive, destruction of life during the closing stages of the glacial period, and immediately after, in which man may fairly be assumed to have shared to a great extent.

The alleged object of the flood, namely, the destruction of the human race, may then well have been accomplished by submergence limited to central and western Asia, from which I have brought much new evidence going to show that at a very recent geological period, indeed since man's existence, there have been such changes of land level as render it easier than before to credit the existence of a great fact underneath the widespread traditions concerning a deluge in which the last remnants of the human race, except those saved by special arrangement, were destroyed.

G. Frederick Wright.

It must be left to readers of the Monthly to decide whether or not Professor Wright answers the questions addressed to him by our correspondent. They were as follows:

1. You say, Professor Wright, that "The Paleolithic man of science may well be the Antediluvian man of Genesis." Was Tubal Cain, 'an instructor of every artificer in brass and iron,' an antediluvian man, and, if so, had he not learned to use smoothed stone instruments? Was Noah, himself, a paleolithic or a neolithic man, and did he build the ark with flaked or polished flint implements?

2. You say: "But towards the close of this period there were 120 years (specially mentioned in the Bible as a time of warning) in which the movement was accelerated to such a degree that the rising waters gave point to the preaching of Noah." The period of 120 years here mentioned was deduced from the statement that Noah was 600 years old at the time of the flood. Do you believe that Noah was 600 years old, and that his grandchildren that peopled the earth were subsequently born?

3. You say: "During the last 371 days of this period the catastrophe culminated in the facts specifically related in the Book of Genesis." Do you believe that the 'facts specifically related in the Book of Genesis' are true? For example, that "every living substance was destroyed which was upon the face of the ground, both man, and cattle, and the creeping things, and the fowl of the heaven; and they were destroyed from the earth: and Noah only remained *alive*, and they that *were* with him in the ark."

SCIENTIFIC LITERATURE.

THE STARS.

PROFESSOR NEWCOMB, in the last issue of the 'Science Series' (Putnam), sums up our present knowledge of the stars. The greatest problem which can engage the human mind is the structure and duration of the Universe. This is the problem which the author proposes in the fourteenth chapter, and which he discusses throughout the rest of the volume. The early chapters may be regarded as forming an introduction to this far-reaching investigation. To present a popular statement of the facts of astronomy is no simple task. This the author keenly appreciates, for in the preface he admits that he has failed to satisfy himself. Nevertheless, no one could be better prepared to undertake the work than Professor Newcomb, and the outcome cannot fail to meet with general praise. The author possesses that rare style, which comes from a perfectly clear conception of the subject, and a good command of plain English. He can be exact without the use of technical language.

Among the important subjects, which are discussed in the volume, are the surveys of the stars, which are now in progress. These surveys are of different kinds. There are the cataloguing and numbering of the stars, which are still actively carried on, and by new and novel methods, due to the introduction of photography. To count and fix the positions of the stars is, however, not enough. There must also be photometric surveys, to determine the exact brightness, and other surveys for the systematic study of the spectra, the parallax, and the motions of the stars. There must also be careful surveys of the nebulæ. A most interesting investigation is that of the motion of stars in the line of sight, a study which has reached a wonderful precision at the Lick Observatory, with the great refractor and its spectroscope. This has thrown much light on the subject of double and variable stars. Other subjects of special interest are the great numbers of variable stars, which are found packed into a few dense clusters, and the life history and changes of a star. At present, owing to the incompleteness of the surveys and other studies no entirely satisfactory discussion of the structure of the Universe is possible. The subject, however, is treated in an extremely clear and interesting manner, and all the conclusions are drawn, in regard to the Universe, which the present state of the science permits.

ALASKA.

A NOTABLE book on Alaska has recently left the press of Doubleday, Page & Company (New York) in the form of a report on the Harriman Alaska Expedition of 1900. This expedition was organized by Mr. E. H. Harriman as a means of obtaining definite information concerning the characteristics and resources of the Alaskan coast and interior; and through the cooperation of the Washington Academy of Sciences a strong scientific character was impressed on the work. The personnel included a 'scientific party' of twenty-five specialists, several of them eminent in their respective lines; and every possible facility for original work was afforded these specialists in the course of the voyage and land journeys, so that important records and collections were obtained. The preparation of the material for publication was undertaken largely by members of the Washington Academy, and the papers

have been edited by Dr. C. Hart Merriam, one of the leading contributors to the success of the expedition. The report, as now published, consists of two volumes, but others are promised as remaining material is elaborated. The first volume is largely made up of the narrative of the expedition by the littérateur-naturalist, John Burroughs, and an account of the natives of the Alaska coast region by Dr. George Bird Grinnell. The second volume contains memoirs on the discovery and exploration of Alaska, by Dr. William H. Dall; on Alaskan birds, by Professor Charles Keeler; on the forests of Alaska, by Professor B. E. Fernow; on the geography of Alaska, by Dr. Henry Gannett; on the Alaskan atmosphere, by Professor William H. Brewer; on 'Bogoslof, Our newest volcano,' by Dr. Merriam; on the salmon industry, by Dr. Grinnell, and on fox farming, by M. L. Washburn. Each of these memoirs is a substantial contribution to knowledge of the territory; the whole constitutes a standard source of information concerning Alaska and its resources and possibilities. The volumes are no less notable in form than in substance; they are models of bookmaking technique. Convenient in form and size, they are sumptuous in effect and finish; typography and paper are irreproachable, the binding is appropriate, and the illustrations are adequate and well distributed. These illustrations are especially fine. There are 39 lithograph plates, showing landscapes, glaciers, flowering and fruiting plants, birds, mammals, etc., with unsurpassed fidelity and refinement; and there are 85 photogravure plates, showing characteristic views of the region with an accuracy and fulness of detail seldom attained and never excelled, some of the pictures of glaciers and bergs, for example, being revelations of the possibilities of photo-mechanical reproduction. These admirable plates are supplemented by 240 text cuts, mainly reproductions of drawings notable alike for faithfulness to nature and for artistic perfection.

SOCIOLOGY.

Professor Giddings's new book, 'Inductive Sociology' (The Macmillan Company), is an elaboration of the theories set forth in his previous work on 'The Principles of Sociology.' The present volume covers, however, only one half of the field marked out by the author as general sociology. Its object is, in the author's words, "to present a scheme of inductive method, a somewhat detailed analysis and classification of social facts, and a tentative formulation of the more obvious laws of social activity." Studies of the historical evolution of society and of the deeper problems of causation are deferred for future consideration.

The volume is divided into two books, the first of which deals with social theory, the second with the elements and structure of society. In the first book a new solution is suggested for the puzzling problem of the unit of society. Mr. Giddings maintains that the true unit is neither the individual nor the family but the 'socius.' This introductory book also contains an admirable analysis of the methods of sociology, which is better by far than anything that has been presented since Comte's classification, and is in many respects an improvement upon this earlier attempt. The second book is divided into four parts, dealing respectively with the social population, the social mind, social organization and social welfare. Within each part the material is classified under separate categories, and the special subjects set forth in a series of propositions, distinctions and definitions. To show how sociology can be systematized, a number of statistical tables, formulæ, diagrams and maps are presented; and to encourage further investigation along these lines, blank forms are furnished for the collection and consideration of sociological data.

THE PROGRESS OF SCIENCE.

WINTER MEETINGS OF SCIENTIFIC SOCIETIES.

The efforts to secure a convocation week for the meetings of scientific and learned societies have met with gratifying success. It may be remembered that a note in a former issue of this magazine called attention to the appointment of a committee of the American Association for the Advancement of Science which secured the cooperation of the Association of American Universities. Most of our leading institutions have now decided to set apart for these meetings the week in which the first of January falls. In some cases no change in the calendar was required, in others it has only been decided that officers may have leave of absence, but in many the Christmas holidays have been lengthened by a few days. The movement has met with practically universal approval, both on the part of institutions of learning and on the part of scientific societies, and represents a gain for science, the importance of which can scarcely be overstated. The advancement and the diffusion of science depend largely on the meetings of our societies. It is of the utmost importance for scientific men to come together and discuss their common interests. Only so can a high and uniform standard be maintained throughout the country, only so will an eager interest in advanced work and research be maintained, only so will men find their proper places and the work they are best able to do, only so will science be adequately recognized and supported by the community. Hitherto the scientific meetings have been divided between summer and winter. The American Association has met in the summer holidays and with it the societies devoted to the physical sciences. In midsummer it is impossible for many to attend the meetings, and those who do suffer great personal inconvenience; the week between Christmas and New Year's Day is too short, breaking into Christmas time and being interrupted by Sunday. This year, for the first time, the week after that in which Christmas falls has been recognized as convocation week, and affords a convenient time for the meetings.

The council of the American Association for the Advancement of Science meets at Chicago on January 1, and the Section of Anthropology of the Association holds a winter meeting at Chicago. The Association will hold a summer meeting at Pittsburgh next year, but will hold a winter meeting in Washington in the following convocation week. The American Society of Naturalists meets at Chicago on December 31 and January 1, in conjunction with the Western Naturalists, and the national societies devoted to morphology, bacteriology, anatomy, physiology and psychology will meet at the same place and on the same days and on the days immediately preceding and following. Other societies meet elsewhere this winter; but it is expected that they will all meet at Washington next year, and that it will be possible hereafter to bring together at least once in three years the great majority of those engaged in scientific work in America.

THE PRESIDENT'S MESSAGE.

President Roosevelt's message to the Congress has been more widely read and more generally approved than any other recent document of this kind.

It contains no platitudes worded in questionable English; it is a vigorous expression of a straightforward and hopeful policy that is American rather than partisan. Such a message should do something towards making obsolete that form of party government which leads one half the people to prevent the other half from doing anything. Even in directions such as the maintenance of the present tariff and the enlargement of the navy, where the president's policy is opposed by a strong minority, it seems that he expresses the general sense of the nation, and in any case the division is not along the inherited party lines.

Apart from the emphasis on efficiency and expertness in all departments of the government which gives the whole message a certain scientific coloring, there are several recommendations that are directly concerned with science and its applications. Three great engineering works are urged—the Isthmian Canal, the Pacific Cable and Irrigation. These enterprises are directly dependent on applied science, and their accomplishment, under the direction of American engineers, will give new opportunities for scientific progress. It appears that we may need to go to Great Britain for the cable, but this ought not to be necessary five years hence. In the case of forestry and irrigation, which are said to be perhaps the most vital internal questions of the United States and are discussed at greater length than any others, the president fully realizes the need of expert and scientific direction. It is recommended that the scientific bureaus concerned with these subjects be united and put under the Department of Agriculture. Concerning this department the president says:

"The Department of Agriculture during the past fifteen years has steadily broadened its work on economic lines, and has accomplished results of real value in upbuilding domestic and foreign trade. It has gone into new fields until it is now in touch with all sections of our country and with two of the island groups that have lately come under our jurisdiction, whose people must look to agriculture as a livelihood. It is searching the world for grains, grasses, fruits and vegetables especially fitted for introduction into localities in the several states and territories where they may add materially to our resources. By scientific attention to soil survey and possible new crops, to breeding of new varieties of plants, to experimental shipments, to animal industry and applied chemistry, very practical aid has been given our farming and stock-growing interests. The products of the farm have taken an unprecedented place in our export trade during the year that has just closed."

The president recommends the creation of a cabinet officer, to be known as secretary of commerce and industries. He calls attention to the important work of the Smithsonian Institution and the needs of the National Museum. He emphasizes the value of the 'National Library,' and advocates a permanent census bureau 'for the sake of good administration, sound economy and the advancement of science.'

THE NAVAL OBSERVATORY.

The President does not refer in his message to the U. S. Naval Observatory, but he doubtless approves the recommendations in the report of Secretary Long, which, if carried into effect by the Congress, will remove the difficulties which have so long interfered with the scientific work of our national observatory. Secretary Long says:

"Attention is called to the first and very important report of the board of visitors to the Naval Observatory. I earnestly commend its recommendations to careful consideration. This board was created by act of Congress in March last. I believe its visitations will be found valuable in making the

observatory efficient and in rank with the best institutions of the land. It appears that no other observatory in the world has the expenditure of so much money, but also that its results are not commensurate with those of some other observatories the expenditures of which are less. Its head should of course be the best astronomer, who has proper administrative qualifications, that can be found in the country. It is especially desirable that he should have continuity of tenure, as the observatory has undoubtedly suffered from frequent changes in its superintendents.

"While the average term of service of superintendents at Greenwich has been twenty-eight years and at Harvard fifteen, at the Naval Observatory it has been only a little over three. I urgently recommend that the legislation of the last Congress to the effect 'that the superintendent of the Naval Observatory shall be, until further legislation by Congress, a line officer of the navy of a rank not below that of captain,' be repealed, and that on the contrary it be enacted that there shall be no limitation upon the field from which the superintendent is to be selected. As well might the above-quoted statute have provided that the commissioner of fish and fisheries should be selected from the line of the marine corps, or the director of the Geological Survey from the line of the army.

"There is no vital relation between the navy and the observatory. It may happen that some naval officer is preeminently qualified for such a place, in which case he would be appointed to it, but the country is entitled to have unlimited range of selection. The present limitation, which shuts out the whole body of civilian astronomers and even any astronomer in the navy who does not happen to be in the line, or, if in the line, below the rank of captain, is peculiar. Only a very small proportion of naval officers are not below the rank of captain, and as most of them are required for naval services—a requirement which is now increasing—the list from which selection can be made is a noticeably small one. It is evident, too, from the wording of the above quotation from the statute, that Congress in passing it had in mind further legislation in this respect."

WORK OF THE DEPARTMENT OF AGRICULTURE.

The report of the Secretary of Agriculture for the past year shows that progress has been made in strengthening the organization of the National Department of Agriculture, and in increasing the breadth and efficiency of its scientific work. Four bureaus have been organized for the purpose of bringing together more closely the allied lines of work and providing for the expansion which has been authorized by Congress in other lines. These are the Bureaus of Plant Industry, of Soils, of Forestry and of Chemistry. The Bureau of Plant Industry, the creation of which has involved the most reorganization of any of the new bureaus, combines under one head the work in nine different branches, each presided over by an expert, and with a corps of more than two hundred efficient workers. The unification of work and the closer cooperation which have resulted, together with the economy of time in administration, lead the secretary to recommend a further extension of the bureau system in the department. He announces that preliminary plans have been procured for a new agricultural building, providing facilities for bringing together all the administrative and laboratory work in the various lines under one roof.

The report shows that the department has been alert in its efforts to extend the markets for our agricultural products abroad, and no less so in seeking to bring about the production in this country and its new possessions of a large part of the $400,000,000 worth

of products which are at present imported. One half of this now comes from such climates as prevail in Hawaii, Porto Rico and the Philippine Islands, and the secretary declares that 'it is the privilege and duty of the department of agriculture to teach the people of those islands to produce what we now buy from tropical countries.' The establishment of experiment stations in Hawaii and Porto Rico during the year was an important step in that direction. Both these stations have been placed in charge of men sent out from the department, which has also furnished the chief of the new Bureau of Agriculture for the Philippines, established under the War Department in October. An experiment station for the Philippines, to work in cooperation with the new bureau, is strongly recommended. The efficient and valuable work of the experiment stations all over the country is becoming more apparent every year, and a broader, deeper foundation of scientific inquiry is being laid. Cooperation between the department and the stations has greatly increased, so as to meet the varied national and local needs of agriculture and extend the benefits of agricultural investigation to every part of the Union. This cooperation is taking a variety of forms, such as experiments to find grasses, forage crops and cereal grains better adapted to particular localities; experiments in range renovation and management, which are sorely needed in some sections of the West; studies of the water requirements of crops in the irrigated region and of the problems of water conservation and management; soil studies; sugar-beet production; plant-breeding experiments, and studies on the food of man, its preparation and use. In the recent development of the department's work, forestry, soil studies and irrigation have assumed places of prominence. The forestry work, besides the investigations in that subject, deals with the preparation of working plans for the management of forests. Applications for such plans covering over 52 million acres are now on file, a number being from large lumbering companies. The soil survey is being carried on in different parts of the country, and numerous fundamental problems are studied in the laboratories. A new feature of this work will be in the field of soil climatology, a field which is practically new to science. The irrigation studies have not been confined to the arid western states, but have been continued on a more extensive plan in the humid climates, such as Louisiana, Missouri, Wisconsin and New Jersey, indicating that 'irrigation is to have a wide field of usefulness in many sections where it is not a necessity.' The secretary expresses himself at length on the subject of national aid for irrigation, holding that public aid will be necessary in the construction of certain irrigation works, and that reservoirs located in the channels of running streams should be public works, but he holds that the first step toward national aid should be the passage of enlightened codes of water laws by the states to be benefited. In the various other lines of research—in studies of plant diseases and insect pests, the origination or discovery of plants more resistant to disease or climate, the fermentation of tobacco, and the preparation and application of serums and toxins for combating animal diseases—the same spirit of progress has characterized the work as in previous years, and results of much practical as well as scientific importance are announced.

THE NEW STAR IN PERSEUS.

No more striking astronomical discovery has been made in recent years than that of the moving nebulous masses around Nova Persei. That remarkable star, now apparently a gaseous nebula, is still of about the sixth magnitude. Flammarion, An-

toniadi and others, found on photographs of the star a halo, which did not appear about other stars on the same plate, and which was thought to be nebulous. Later it was shown by Professor Max Wolf that this aureole was instrumental, and due to the fact that the Nova was rich in rays for which the lenses were uncorrected. At the same time Wolf found that the Nova was surrounded by a faint nebulosity. Long exposures with the powerful reflecting telescopes of the Yerkes and Lick Observatories showed well this nebulosity, and, especially, nebulous patches at considerable distances from the Nova. From later photographs it was announced from the Lick Observatory and confirmed at the Yerkes Observatory, that these nebulous masses are moving away from the Nova. This is a discovery of the highest importance, having a direct relation to the theory of new stars. The motion of the nebula is very great, amounting to about 1′ of arc in six weeks. Carried backward this motion would bring the nebulous masses at the Nova, when the outburst occurred, a fact of much interest. What this rate of movement represents in miles per second cannot be assumed safely until the star's parallax is known. This has not yet been determined. Our nearest neighbor among the stars, so far as known, has a parallax of less than 1″. A parallax as great as 1″ would indicate a velocity of something like 1,500 miles per second. Either the Nova is very near us, or else the velocity of the Nebula is almost inconceivably great. Indeed, if the parallax should prove to be too small for measurement, the fact would imply a velocity so great that it might be better explained as a motion of light, rather than of matter. The motion, moreover, appears not to be radial, but spiral. The broadening of the lines of the spectrum of the Nova furnishes a clue to the rapidity of motion, the value of which is, however, very doubtful. No definite conclusions can be safely drawn until more data are obtained, and a satisfactory determination of the parallax is given. Meanwhile the astronomical world is watching the developments with the keenest interest. Incidentally the investigation is furnishing a powerful argument for a more extended use of large reflecting telescopes. It may be, that the Golden Age of the refracting telescope has passed!

THE MAGNITUDE AND THE MASS OF THE VISIBLE UNIVERSE.

An interesting question which often occurs to the astronomer and the physicist is that of the magnitude and the material contents of the visible universe. While science is unable at present to give a decisive answer to this question it is nevertheless competent to correlate the observed facts to such an extent that a possible, if not a probable, answer is already attainable. The latest contribution to this subject is due to the indefatigable labors of Lord Kelvin. In the 'Philosophical Magazine' for August, 1901, he attacks the question from the dynamical side in an article 'On ether and gravitational matter through infinite space'; and at the September meeting of the British Association for the Advancement of Science he amplified his investigation in a paper on 'The absolute amount of gravitational matter in any large volume of interstellar space.'

The data for Kelvin's investigation are as follows: The part of the universe visible to us may be considered to lie within a sphere having a radius equal to the distance of a star whose parallax is one thousandth of a second of arc. This distance is about thirty thousand million million kilometres; a distance so great that light would require about three thousand years to traverse it. The number of stars, luminous and non-luminous, within this sphere, Kelvin estimates to be something like one thousand million. This agrees well with the figures of

Newcomb and Young who have estimated that the visible stars are fifty to one hundred millions in number. Assuming the average mass of these stars to be equal to the mass of our sun, the amount of mass in the visible universe is about 2×10^{30} metric tons.

Now, if these thousand million suns had been uniformly distributed within the sphere in question, and had started from rest twenty-five million years ago, they would have acquired under the law of gravitation about such velocities as the stars are now observed to possess; or, if thousands of millions of years ago they started from rest at mutual distances asunder, very great in comparison with the radius of the supposed sphere, and so distributed that they would now be temporarily equally spaced in that sphere, their mean velocities would be of the same order as that actually observed. A non-uniform initial distribution of the suns would give higher velocities for the stars than the observed values; and any great increase in the assumed number of suns would require far greater velocities than the observed values. Hence Kelvin infers that the amount of mass in our universe is greater than one hundred million times and less than two thousand million times our sun's mass.

That there would be plenty of room for a thousand million suns in the assumed sphere is shown by a striking calculation made by Kelvin. Thus, if the suns were placed severally at the centers of the thousand million cubes into which their enclosing sphere may be supposed to be divided, then each sun would be nearly fifty million million kilometres from each of its six nearest neighbors. This distance is a little greater than the distance of the nearest fixed stars from our solar system.

SCIENTIFIC ITEMS.

THE great Nobel prizes, each of the value of about $40,000, have now been awarded for the first time as follows: In Medicine to Professor Behring, in physics to Professor Röntgen, in chemistry to Professor van't Hoff. The prize for the promotion of peace has been divided between Dr. Dumant and M. Passy, and the prize in literature has been awarded to M. Prudhomme.

THE Copley Medal of the Royal Society has been awarded to Professor J. Willard Gibbs, of Yale University.—Director W. W. Campbell, of the Lick Observatory, has been elected an associate member of the Royal Astronomical Society.—Professor F. Lamson-Scribner, of the United States Department of Agriculture, has been given charge of the Bureau of Agriculture established in the Philippines.

THE most important scientific news of the month is Mr. Carnegie's offer of $10,000,000 to endow a national university or institution for scientific research at Washington. The national government hesitates to accept the bonds of the United States Steel Corporation offered by Mr. Carnegie, but this is a detail which will doubtless be arranged.—On the same day that Mr. Carnegie's gift became known, it was announced that Mrs. Stanford had signed the final papers transferring property, estimated at $30,000,000, to Leland Stanford Junior University. It appears that the endowment of Stanford is now about equal to the combined endowment of our three richest universities—Harvard, Columbia and Chicago.

GREAT NEBULA IN ANDROMEDA.

PHOTOGRAPHED WITH THE TWO-FOOT REFLECTING TELESCOPE OF THE YERKES OBSERVATORY (RITCHEY).

THE POPULAR SCIENCE MONTHLY.

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STELLAR EVOLUTION IN THE LIGHT OF RECENT RESEARCH.*

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MANY attempts have been made to sum up the work of the nineteenth century, and to define its principal lines of progress. In estimates of the relative importance of the books published during this period there has been some divergence of view, but regarding one of them no element of doubt seems to have entered the minds of the critics. By unanimous consent Darwin's 'Origin of Species' is accorded a commanding position among the works which have influenced the intellectual life of the century. It would be difficult to overestimate the effect which the doctrine of evolution has wrought. The principle of orderly and harmonious development which it embodies has found application, not only in explaining the wide diversity of organic species, but in unifying the events of history, in elucidating the origin of language, and in throwing light on difficult questions in every department of human knowledge. The idea of evolution may indeed be traced back through the writings of many centuries. The early philosophers, though not possessed of the immense collection of recorded phenomena by which modern men of science may test their theories, were constantly occupied with great problems demanding the widest generalization. In attempting to account for the earth and its inhabitants they made the first steps in the direction which Darwin subsequently pursued.

* Revised from an address delivered on June 5, 1901, before the Minnesota Chapter of the Honorary Scientific Society of Sigma XI, University of Minnesota.

It would be interesting to recall the strange traditions in which primitive peoples have recorded their vague imaginings of the origin of things. But the absence of even an attempt at careful reasoning renders such tales of no value for our present purpose. The Greek philosophers were not oblivious to the value of observation as a check on speculation regarding the solar system, but the instruments then available were too crude to give accurate positions of the heavenly bodies. Even Copernicus, though he established the sun at the center of our system, and thus paved the way for the nebular hypothesis, retained the epicycles of the Greeks. Kepler, basing his investigations upon the observations of Tycho Brahe, proved that the planets move in ellipses with the sun at the focus, and removed all vestige of doubt as to the general plan of the solar system. The harmony which characterizes the motions of the planets and a knowledge of the effect of gravitation led Kant to formulate an explanation of the origin of the solar system, which subsequently found more perfect expression in the nebular hypothesis of Laplace.

In this hypothesis Laplace seeks to account for the formation of the sun and planets through the contraction of a vast nebulous cloud, which once filled the entire solar system, extending to the orbit of Neptune. This mass, which he considered to be fiery hot, was supposed to be in rotation. As it cooled, through radiation into space, it contracted toward the center. The result of this contraction was to increase the velocity of rotation, and when through increasing velocity the centrifugal force at the periphery counterbalanced the attraction of the central mass, a ring was thrown off. Further contraction resulted in the formation of other rings, in each of which the matter collected about its densest part, and thus produced a planet. Before they had time to cool these planets in turn threw off rings, which, with the single exception of Saturn's ring system, condensed into satellites.

This celebrated hypothesis, though unsupported by mathematical proof, has occupied a dominant position since the time of its publication more than a century ago. It has been subjected to much criticism, but most of the objections raised by Faye and others have been met by modifications of the hypothesis. Of late it has encountered fresh attacks on the part of Chamberlin and Moulton, and it now seems doubtful whether it will be possible to overcome their criticisms, which are based on dynamical considerations. It may prove to be sufficient, however, to forsake the lenticular mass of vapor predicated by Laplace in favor of the spiral form which Keeler has shown to characterize so many nebulæ.

The nebular hypothesis seeks to account for a system like our own, wherein a central sun is surrounded by planets and satellites, originally self-luminous, but ultimately cooled to the point where they are lumi-

nous only through reflected light. The stars are so distant from us that any planets which may attend them are beyond the reach of the most powerful telescopes. In some of the planetary and spiral nebulæ, such as the Great Nebula in Andromeda (Fig. 1), we perhaps

FIG. 2.

STAR-TRAILS PHOTOGRAPHED WITH TWO AND ONE-HALF INCH PORTRAIT LENS (RITCHEY).

observe the earlier stages of the process of condensation, but no distinct evidence of progressive change has yet been gathered from telescopic observation. In seeking for evidence of stellar evolution, on a plan comprehensive enough to include a place for every star in the heavens,

we may begin with visual and photographic observations with the telescope. Such remarkable photographs as that of the Andromeda nebula seem to bring us into the very presence of a greater system, more nearly comparable in size with the Milky Way than with the solar system, in the actual process of formation. But on account of the long periods of time, which must elapse before changes in this distant mass may become sufficiently great to be appreciable, and for many other reasons, we could not hope to base a complete scheme of stellar evolution on such photographs alone. Our observational methods must also include the means of solving physical, chemical and gravitational problems as they present themselves, not close at hand in the laboratory, but at inconceivably distant regions of space. For this reason it would have been impossible prior to the invention of the spectroscope to arrange the stars according to any clearly defined system of development. The principal advances which have been made in the study of stellar evolution are therefore confined to the period which has elapsed since the middle of the nineteenth century.

Thus the investigation of stellar evolution has been contemporaneous with the investigation of organic evolution. Indeed, the epoch-making discovery of the chemical composition of the sun by Kirchhoff and Bunsen was made in the year of the publication of the 'Origin of Species.' Before this discovery the meaning of spectral lines had been as obscure as the meaning of Egyptian hieroglyphs prior to the discovery of the Rosetta stone. After it the chemical analysis of a star became hardly less difficult than the analysis of an unknown substance in the laboratory. Furthermore, it soon became apparent that the light of a star, as decomposed by a prism, was competent to define the star's position in a general scheme of development, in which every advance, from the unformed nebulous cloud on through the highest degree of stellar brilliancy to such a final stage as is typified by the moon, can be defined with but little danger of error. Before we proceed to consider some of the evidences of stellar evolution, let us examine some of the instruments and methods without which the discoveries to be subsequently described would have been impossible.

I shall confine my remarks on modern astrophysical instruments to those at present employed at the Yerkes Observatory, partly because nearly all the celestial photographs reproduced in the figures were taken with these instruments and partly because of the convenience of illustrating them. But before describing the great telescope which forms the principal apparatus of the observatory, I wish to point out that many of the most important results of astronomy, results which could not be obtained with a powerful telescope for the very reason of its great power—have been derived from the use of an ordinary camera, with just such a lens

as is found in the possession of thousands of amateur photographers. If we take an ordinary camera and point it on a clear night toward the north pole, it will be found after an exposure of one or two hours that the stars which lie near the pole have drawn arcs of circles upon the plate (Fig. 2). This is due to the fact that the earth is rotating upon its axis at such a rate as to cause every star in the sky to appear to travel through a complete circle once in twenty-four hours. The nearer the star to the pole the smaller does this circle become. As we move away from the pole we find the curvature of the star trails growing less and less, until at the equator they appear as straight lines.

Just such photographs as these are frequently employed in astronomical investigations; *e. g.*, for the purpose of recording variations in a star's brightness, which would be shown on the plate by changes in the brightness of the trail. But for most purposes it is desirable to have photographs of stars in which they are represented as points of light rather than as lines. To obtain such photographs it is necessary to mount the camera in such a way that it can be turned about an axis parallel to the earth's axis once in twenty-four hours. A camera so mounted becomes an equatorial photographic telescope, differing in no important respect save in the construction of its lens from an instrument like the 40-inch Yerkes telescope.

But the scale of the photographs obtained with such a camera differs in marked degree from that of the photographs furnished by the telescope. Here, for example, is a region of the Milky Way photographed by Professor Barnard with one of the old-fashioned lenses formerly employed in portrait galleries (Fig. 3). Such a picture as this is of the greatest service in all studies of the structure of the Milky Way, for it brings before us at a single glance an immense region of the sky, thus permitting us to trace the general features which are common to this area. You will notice in the midst of this star cloud a little cluster of stars, here so densely packed together that no details of the cluster can be distinguished. If our investigations required us to single out some individual star in the cluster, perhaps for the purpose of analyzing its light, it is evident that the portrait lens would prove inadequate for our purpose. It is in such a case as this that an instrument like the 40-inch telescope comes into play. The camera with which this photograph was taken has a lens six inches in diameter, of thirty-one inches focal length. The great telescope has a lens forty inches in diameter, of sixty-four feet focal length. Thus the scale of the photographs made with the telescope is about twenty-five times that of the photographs made with the portrait lens. The portrait lens covers a large area of the sky on a very small scale, while the field of the telescope is limited to a small region, which is depicted on a large scale. Let us see the difference between the two instruments

as illustrated by the photographs themselves (compare Fig. 3 with Fig. 4). The small cluster, which in reality contains several thousands of stars, is resolved by Mr. Ritchey's photograph taken with the large telescope into all its constituent parts, stars less than one second of arc apart being clearly separated on this great scale.

Fig. 3.
Star Cluster Messier 11 and the surrounding Milky Way.
Small scale photograph taken with portrait lens (Barnard). (The cluster, here about one-sixteenth of an inch in diameter, lies just above the middle of the picture.)

Having seen this illustration of the superior power of the large telescope you may perhaps be interested to become more closely acquainted with the instrument itself (Fig. 5). The great weight of the 40-inch lens, amounting with its cell to half a ton, requires that the tube which supports it, here taking the place of the camera box of the previous instrument, shall be of immense rigidity and strength. This

tube, 64 feet in length, is supported at its middle point by the declination axis, which in its turn is carried by the polar axis, adjusted to accurate parallelism with the axis of the earth. By means of driving mechanism in the upper section of the iron column the whole instru-

FIG. 4.
STAR CLUSTER MESSIER 11.
Large scale photograph taken with the forty-inch Yerkes telescope (Ritchey).

ment is turned about this polar axis at such a rate that it would complete one revolution in twenty-four hours. Although the moving parts weigh over twenty tons the telescope can be directed to any part of the sky by hand, but this operation is much facilitated by the use of electric

motors provided for the purpose. When once directed toward the object to be observed it will frequently happen that the lower end of the telescope is far out of reach above the observer's head. For this reason the

FIG. 5.
THE FORTY-INCH TELESCOPE OF THE YERKES OBSERVATORY.

entire floor of the observing room, 75 feet in diameter, is constructed like an electric elevator, which by throwing a switch can be made to rise or fall through a distance of twenty-three feet. Thus the lower end of the telescope is rendered accessible even for objects near the

horizon. In order that the observing slit may be directed to any part of the sky the dome, 90 feet in diameter, is mounted on wheels and can be turned to any desired position by means of an electric motor controlled from the rising-floor.

The telescope is used for a great variety of purposes in conjunction with appropriate instruments, which are attached to the lower end of the tube near the point where the image is formed. I have already shown a photograph of a star cluster taken with this telescope, but without describing the process of making it. As a matter of fact the object-glass of the 40-inch telescope was designed for visual observations, and its maker, the late Alvan G. Clark, had no idea that it would ever be employed for photography. Without dwelling upon the distinguishing features of visual and photographic lenses I may say that the former is so designed by the optician as to unite into an image those rays of light, particularly the yellow and the green, to which the eye is most sensitive. With the only varieties of optical glass which can be obtained in large pieces it is impossible to unite in a single clearly defined image all of the red, the yellow, the green, the blue, and the violet rays which reach us from a star. Therefore when the optician decides to produce an image most suitable for eye observations he deliberately discards the blue and violet rays, simply because they are less important to the eye than the yellow and green rays. For this reason the image of a star produced by a large refracting telescope is surrounded by a blue halo containing the rays discarded by the optician. These very rays, however, are the ones to which the ordinary photographic plate is most sensitive; hence in a photographic telescope the blue and violet rays are united, while the yellow and green rays are discarded.

The 40-inch telescope is of the first type, constructed primarily for visual observations. In order to adapt it for photography Mr. G. W. Ritchey of the observatory staff simply places before the (isochromatic) plate a thin screen of yellow glass, which cuts out the blue rays, but allows the yellow and green rays to pass. As isochromatic plates are sensitive to yellow and green light there is no difficulty in securing an image with the rays which the object-glass unites into a perfect image. During the entire time of the exposure a star which lies just outside the region to be photographed is observed through an eye-piece magnifying 1,000 diameters. This eye-piece is attached to the frame which carries the photographic plate, and is susceptible of motion in two directions at right angles to each other. In the center of the eye-piece are two very fine cross-hairs of spider web illuminated by a small incandescent lamp. If the observer notices that through some slight irregularity in the motion of the telescope, or through some change of refraction in the earth's atmosphere, the star image is

moving away from the point of intersection of the cross-hairs, he instantly brings it back by means of one or both of the screws. As the plate moves with the eye-piece it is evident that this method furnishes a means of keeping the star images exactly at the same point on the plate throughout the entire exposure. With such apparatus data are gathered for the study of stellar development.

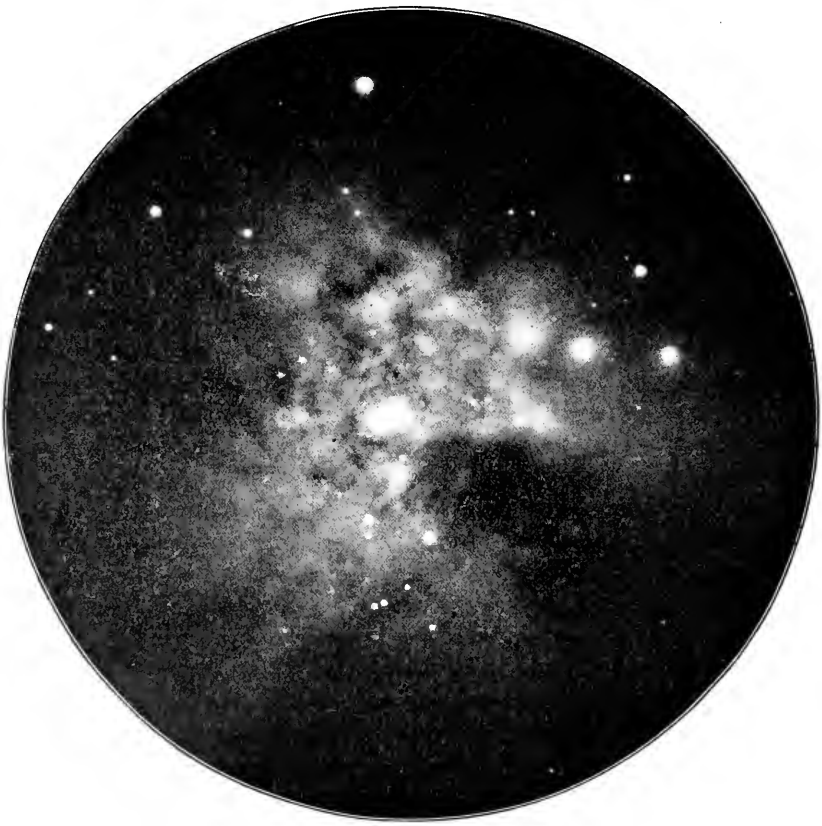


FIG. 6.
GREAT NEBULA IN ORION.
Photographed with the forty-inch Yerkes telescope (Ritchey).

It is easier to trace the successive steps in the development of a star after it has been formed than it is to account for its origin. But all the evidence that has been accumulated up to the present time tends to show that stars are condensed out of the cloudlike masses which we know as nebulæ. Less than half a century has passed since the true nature of a gaseous nebula was determined. In his extensive observations of astronomical phenomena Sir William Herschel examined a great number of star clusters similar to that shown in

Fig. 4. His telescope was a large one, but it can safely be said that he never saw a cluster so well as this object can be perceived through the aid of photography. He found in studying object after object in all parts of the heavens that many clusters could be resolved into their constituent stars. In some of these clusters the stars are widely separated by a powerful instrument, as they appear in this photograph. In others, either on account of their greater distance or because the stars are less widely spaced, the central regions are no longer clearly resolvable as separate objects. It is thus quite possible to imagine a cluster in which the stars are so closely grouped that no telescope, however powerful, could separately distinguish them.

Now as a matter of fact we find in all parts of the heavens luminous objects which can not be separated into stars. Some of these are of definite outline and are perfectly symmetrical in form, in many cases with a brilliant star-like nucleus at their center. These are known as the planetary nebulæ. Other nebulæ, like the great nebula in Orion (Fig. 6), are diffuse and irregular and extend over great regions of the sky. It was long a question whether such objects were capable of resolution into stars with a sufficiently powerful telescope. Herschel rightly concluded that an important distinction can be drawn between a nebula and a star cluster, though his son did not admit this distinction.

It was only after Huggins had applied the spectroscope to an analysis of the light of a nebula that it could be said without danger of contradiction that the phenomenon is not one produced by the crowding together of separate stars, but is due to the presence of a mass of incandescent gas. Sir William Huggins' account of his first spectroscopic examination of a nebula is recorded in the first volume of the 'Publications of the Tulse Hill Observatory':

"On the evening of August 29, 1864, I directed the spectroscope for the first time to a planetary nebula in Draco. I looked into the spectroscope. No spectrum such as I had expected! A single bright line only! At first I suspected some displacement of the prism, and that I was looking at a reflection of the illuminated slit from one of its faces. This thought was scarcely more than momentary; then the true interpretation flashed upon me. The light of the nebula was monochromatic and so, unlike any other light I had as yet subjected to prismatic examination, could not be extended out to form a complete spectrum. After passing through the two prisms it remained concentrated into a single bright line, having a width corresponding to the width of the slit, and occupying in the instrument a position at that part of the spectrum to which its light belongs in refrangibility. A little closer looking showed two other bright lines on the side towards the blue, all three lines being separated by intervals relatively dark. The riddle

of the nebulæ was solved. The answer, which had come to us in the light itself, read: Not an aggregation of stars, but a luminous gas."

With this advance a new era of progress began. The power of the spectroscope to distinguish between a glowing gas and a mass of partially condensed vapors like a star established it at once in its place as the chief instrument of the student of stellar evolution. It became apparent that the unformed nebula might furnish the stuff from which stars are made. Observations tending to this conclusion were not long in presenting themselves. In the heart of the Orion nebula are four small stars which constitute the well-known Trapezium. Situated as they are in the midst of this far-reaching mass of gas, it is not hard to picture them as centers of condensation, toward which the play of gravitational forces tends to concentrate the gases of the nebula. It might therefore be expected that stars in this early stage of growth should show through the spectroscopic analysis of their light some evidence of relationship with the surrounding nebula. Now this is precisely what the spectroscope has demonstrated. Not only these stars, but many other stars in the constellation of Orion, are shown by the spectroscope to contain the same gases which constitute the nebula. For this and other reasons they are considered to represent one of the earliest stages of stellar growth.

It may be many years before the exact nature of the process by which a star is formed from a nebulous mass is clearly understood. Shortly before his death the late Professor Keeler made a most important discovery in the course of his photographic work with the Crossley reflector of the Lick Observatory. Spiral nebulæ have long been known, but it was not supposed that they were sufficiently numerous to be regarded as type objects. The great spiral nebula illustrated in Fig. 7 from one of Mr. Ritchey's recent reflector photographs has long been regarded as one of the most remarkable objects in the heavens, and the possible significance of its form had by no means been overlooked. But few astronomers were prepared for Professor Keeler's announcement that the majority of nebulæ are of the spiral form and that many thousands of these objects are within the reach of such an instrument as the Crossley reflector. It does not seem improbable that this spiral form may prove to represent the original condensing mass more truly than the lenticular form from which Laplace imagined the solar system to be evolved.

Enough has already been said to indicate how large a part the methods of spectroscopy must play in a study of the life history of stars. In spite of the common opinion that the spectroscope is an intricate instrument and that the principles of spectroscopy are obscure and difficult of comprehension, it is a fact that the processes used in this field of investigation can be easily understood by any one who will

devote a very small amount of time to the subject. As you doubtless know, the essential feature of a star spectroscope is the prism or train of prisms by which the star light is divided into its constituent parts. After passing through the prisms the light of the star is spread out into a long band, which shows all the colors of the rainbow, beginning

FIG. 7.

SPIRAL NEBULA IN CANES VENATICI

Photographed with the two-foot reflecting telescope of the Yerkes Observatory (Ritchey).

with red at one end and passing through orange, yellow, green and blue, to violet at the other. This band is crossed by lines, and the problem of the spectroscopist is to interpret the meaning of these lines. If the lines are dark he knows that the light of the star after originat-

ing in an interior incandescent body has passed through a mass of cooler vapors, and that during its transmission some of the light has suffered absorption. If, on the other hand, the lines are bright, he knows that the region where they are produced is hotter than that lying below. Thus a single glance at the spectrum of a star is sufficient to give important information regarding the physical condition of its atmosphere.

But the spectral lines are able to tell a far more complete story of stellar conditions. If their exact position in the spectrum can be measured it becomes possible to determine the chemical composition of the star's atmosphere. And here the spectroscopist may be said to have the advantage of the archeologist, in that the key to stellar hieroglyphs is a master key, capable of interpreting not merely the language of a single people or a single age, but of laying bare the secrets of the most distant portions of the universe and applying with equal force to the primitive and to the most highly developed forms of celestial phenomena. If we take a piece of iron wire and turn it into vapor in the intense heat of an electric arc lamp we find that the light which the glowing iron vapor emits, when spread out into a spectrum by a prism, consists of a series of lines characteristically spaced and always occupying the same relative positions. In the same way every other element when transformed into vapor by a sufficiently intense heat emits characteristic radiations, consisting of groups of lines occupying definite positions in the spectrum. It is thus easy to see how the presence of iron vapor can be detected in the atmosphere of Sirius or in that of the sun. In the spectrum of each of these stars we find a group of lines occupying the same relative positions as the lines furnished by the iron vapor in an electric arc. Hydrogen gives an even more characteristic group of lines, which grow closer and closer together as we pass from the red end of the spectrum toward the violet. This group occurs in the spectra of thousands of stars and serves as an important guide in determining a star's place in a general scheme of stellar evolution.

The practical means of carrying out this method of research may be illustrated by a reference to the stellar spectroscope employed with the 40-inch Yerkes telescope. The spectroscope is rigidly attached to the lower end of the telescope tube. The image of a star formed by the 40-inch lens passes into the spectroscope through a slit about one one-thousandth of an inch wide. After analysis by a train of three prisms an image of the resulting spectrum is formed by a suitable lens upon a photographic plate. In making the photograph it is only necessary to keep the image of a star exactly on the slit throughout the exposure, which may occupy from one minute to several hours, the duration depending upon the brightness of the star.

We have seen that a single glance at the spectrum of a star is sufficient to give us important information as to the structure of its atmosphere, while a study of the position of the lines tells what chemical elements are present. We might go on to consider how the width and sharpness of the lines, together with shifts in their position toward the red end of the spectrum, furnish the means of estimating the density of the vapors and the pressure to which they are subjected. The relative intensities of certain lines also serve as a clue to the temperature. Thus in the spectrum of magnesium there is a pair of lines, one of which is the stronger at the temperature of the electric spark, while the other is the stronger at the lower temperature of the electric arc. In the spectra of certain stars the greater intensity of the first line indicates that the temperature is high and approximates that of the electric spark, while in other stars the relative intensities are reversed, indicating that the temperature is lower and corresponds more closely with that of the electric arc. In addition to all this, certain easily measurable changes in the position of the spectral lines are known from Doppler's principle to indicate motion of the star in the direction of the earth. Thus if the lines are shifted toward the red with reference to their normal position, and if we have evidence that the shift is not due to pressure, we may conclude that the distance between the earth and the star is increasing, while if the lines are shifted toward the violet we conclude that the distance between the earth and the star is decreasing. As the earth's motion is known, the velocity of the star in the line of sight can therefore be accurately determined.

After this glance at the methods employed by the spectroscopist, we may return to a further consideration of the stages of stellar evolution. We have seen that the long continued action of gravity tends to produce condensation of a cosmical cloud. The constellation of Orion contains many examples of stars in this early stage of development. As the mass condenses its temperature rises, and corresponding with this rise in temperature and in the density of the vapors which constitute the star we find characteristic changes in the spectrum and also in the star's color. Such a brilliant white or bluish-white star as Sirius or Vega may be taken as representative of the next stage of stellar development. Here the broad bands of hydrogen, which constitute a beautiful series expressible by a simple mathematical formula, serve as the chief mark of distinction. The conditions are not yet ripe for the marked development of metallic lines, though doubtless the numerous elements which constitute the sun and which for the most part are familiar to us on the earth, are present in such stars, though they are not revealed through a study of the spectrum. It is true that evidence exists of the presence of iron and a few other substances, but the lines are thin and few in number and would be overlooked in a

casual examination of the spectrum. The period for their greatest development has not yet arrived. The light gas hydrogen, reaching far above the white-hot mass of condensed vapors which constitutes the nucleus of the star, is at this stage the predominant element, at least so far as we may judge from a study of the light radiation.

An interesting question has arisen regarding the period in a star's life at which the highest temperature is attained. The apparently paradoxical statement of Lane's law that the temperature of a cooling mass of incandescent vapors, instead of falling, actually increases until a certain stage has passed, applies in the present instance. We indeed know that a condensing nebula losing heat by radiation into space will continue to rise in temperature for thousands and even millions of years. A question which has received some discussion of late is with regard to the precise period at which the maximum temperature occurs. Shall we seek it in white stars like Sirius or in yellow stars like the sun, which represents the next well-defined stage of stellar evolution? With an instrument of extraordinary delicacy Professor Nichols has recently measured at the Yerkes Observatory the amount of heat which we receive from Vega and Arcturus. The distance of these stars is so inconceivably great that the quantity of heat which they send to the surface of the earth has hitherto been too small to be detected by the most sensitive instruments. Professor Nichols' radiometer, which in combination with a large concave mirror renders it easy to measure the heat radiated from a man's face 2,000 feet away, proved adequate for the task. He found that Arcturus sends us about as much heat as we should get from a candle six miles away if there were no intervening atmosphere to reduce the candle's intensity. Vega, which to the eye is precisely equal to Arcturus in brightness, was found to send us only half as much heat. If the absorbing atmospheres of Arcturus and Vega were similar in character, it would follow from Professor Nichols' results that Vega, though it sends us less heat, is really the hotter of the two stars. For we know from laboratory experiments that the proportion of long (heat) waves to short (light) waves is greater in the radiation of the cooler of two bodies heated to incandescence. In this case the fact that Arcturus sends the greater amount of heat would be ascribed rather to greater size than to lesser distance, as there is good reason to believe that it is farther from us than Vega.

But unfortunately the dissimilarity of the atmospheres of the two stars renders it uncertain whether such conclusions can safely be drawn. This is particularly true in view of the fact that Sir William Huggins concludes from his spectroscopic studies that the highest stage of stellar temperature is reached in stars like Vega, while stars like Arcturus and the Sun have passed the stage of highest temperature and are already well advanced in their decline.

While some uncertainty must therefore prevail until further investigations have been completed regarding the exact stage at which the highest stellar temperatures are attained, there can be little doubt as to the path which is followed when through the long continued action of gravitation a young star like Vega develops into a star like the Sun. We are fortunate in possessing examples of a great number of intermediate stages in this orderly progress (Fig. 8). As condensation continues, and as the vapors which constitute the star continue to crowd upon each other, the stellar nucleus becomes denser and denser and the vast atmosphere of hydrogen gradually gives place to a much shallower atmosphere, in which hydrogen is still conspicuous, though it no longer predominates in a very striking manner over the other elements. The spectral lines of such elements as iron, magnesium, sodium and cal-

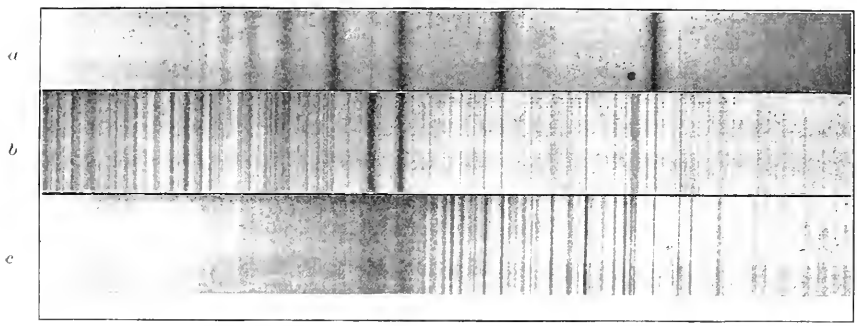


FIG. 8.
CHARACTERISTIC SPECTRA OF (*a*) WHITE, (*b*) YELLOW, AND (*c*) RED STARS (HUGGINS).

cium, rise into prominence as the hydrogen lines fade. Meanwhile the light of the star undergoes a change of color, completely losing its bluish cast and assuming a distinctly yellow hue. There can be little if any doubt that our own sun once passed through the successive stages which are represented by the spectra shown in Fig. 8. The time which has elapsed since it acquired its present size and density as the result of the condensation of the great nebula in which the earth and the other planets also had their origin, covers many millions of years. It is fortunate for the study of stellar evolution that the stages through which the sun once passed are all exemplified in existing stars, which for unknown reasons began their stellar life at widely different times.

It will be profitable to consider for a moment some of the remarkable phenomena which are presented to us by the sun, not only because of their intrinsic interest, but also because it is perfectly safe to assume that similar phenomena, sometimes on a much greater scale, would be presented by other stars, were they not at so great a distance from the earth as to reduce them to mere points of light, even in the most power-

ful telescope. The sun has a diameter of 860,000 miles and, as its distance from the earth is only 93,000,000 miles, an extremely small fraction of the distance of the other stars, it is possible to observe and to study in detail its extraordinary phenomena, which are incomparably more violent than anything observed on the earth. When we speak of the sun we speak collectively of a great number of phenomena, some of which extend for millions of miles from the sun's visible disk. Chief of these is the corona, a vast filmy atmosphere so rare that it offers little or no resistance to the passage of a comet, as it sweeps around the sun under the action of gravitation and returns into the space from which it came. The polar streamers of the corona (Fig. 9) suggest the

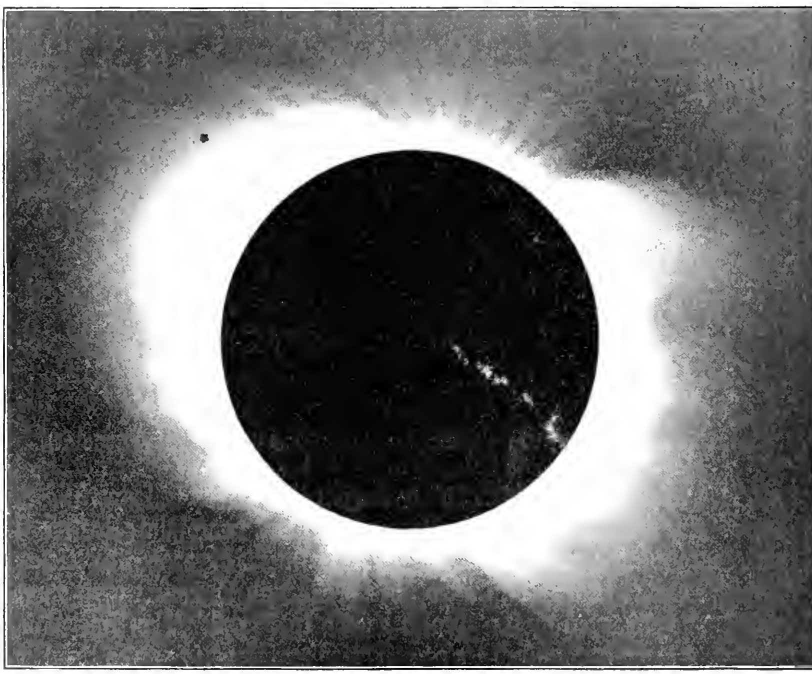


FIG. 9. THE SOLAR CORONA
Photographed by Yerkes Observatory Eclipse Expedition, May 28, 1900 (Barnard and Ritchey).

action of magnetic forces and offer material for long continued study of this, the most mysterious of all the solar appendages. At the base of the corona, rising out of a sea of flame which completely encircles the sun, are the prominences, some of which occasionally attain a height of nearly 400,000 miles. Like the corona, the prominences are hidden by the brilliant illumination of our own atmosphere, and are visible to the naked eye only when the direct light of the sun's disk is cut off by

the interposition of the moon at a total eclipse. But methods have been devised by which they can be observed or photographed on any clear day through the agency of a modified form of spectroscope. The prominences are constantly changing in form, sometimes slowly, as in the case of this group (Fig. 10), a photograph of which, taken at the eclipse of May 28, 1900, by the Astronomer Royal of England in Spain, is shown for comparison with the photograph taken about two hours earlier by the Yerkes Observatory party in North Carolina. Here the

a.

b.

Fig. 10.

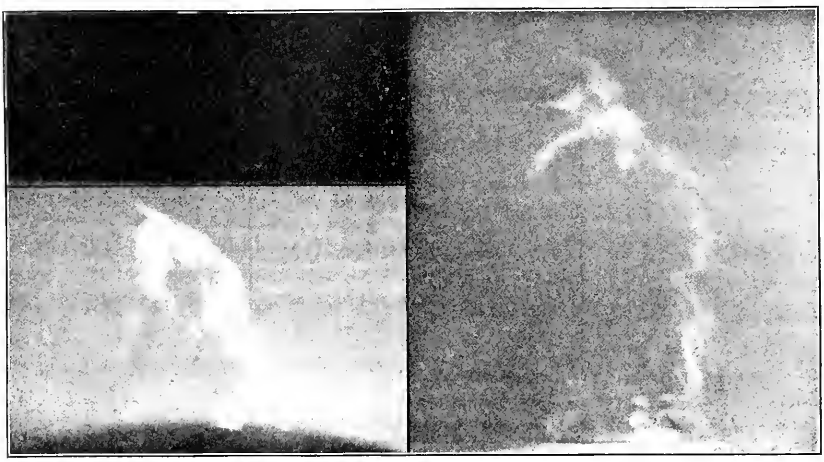
Cloud-like Prominences photographed at the Eclipse of May 28, 1900. *a*, by Yerkes Observatory Party at Wadesboro, N. C. *b*, by Astronomer Royal of England at Ovar, Portugal, two hours later. (The bright cross on the right of this picture is due to a defect in the original photograph.)

change in the form of the mass of gas which constitutes the prominence, is comparatively small, but that violent forces are sometimes at work may be illustrated by photographs of an eruptive prominence taken at the Kenwood Observatory in 1895 (Fig. 11). At the moment when the first photograph was made the prominence had attained a height of 160,000 miles and was rising rapidly. Eighteen minutes later another picture was taken; during the interval the prominence had been going upward at the rate of six thousand miles a minute, and when the exposure was made it had reached an elevation of 280,000 miles. When looked for a few minutes later it had completely disappeared.

The constitution of the chromosphere, the sea of flame some 10,000 miles deep from which the prominences arise, increases in complexity as the surface of the solar disk is approached. In its upper part only the vapor of calcium and the light gases, hydrogen and helium, are found. But in proceeding downward the vapors of magnesium, sodium, iron, chromium, and last of all, carbon, are successively encountered. At this part of the solar atmosphere the dark lines of the solar spectrum take their rise through the effect of absorption.

Time does not permit a detailed description of the phenomena of

the sun's disk. When photographed with an instrument which excludes from the sensitive plate all light except that which is characteristic of the vapor of calcium, its surface is found to be dotted over with extensive luminous regions. Associated with these are the sun-spots, the minute study of which has revealed some strikingly beautiful phenomena, which have been most successfully drawn by Langley. The surface of the sun in the regions devoid of spots is shown by the photographs of Janssen to consist of brilliant granules separated by darker spaces. Much might be said of the peculiar law of rotation of the sun, which causes a point near the equator to complete an axial rotation in much less time than a point nearer the poles. Much might also be said of the periodicity of sun-spots, which at times are



a FIG. 11. *b*

ERUPTIVE PROMINENCE PHOTOGRAPHED IN FULL SUNLIGHT AT THE KENWOOD OBSERVATORY, CHICAGO, MARCH 25, 1895 *a*, AT 10H. 40M. (HEIGHT, 162,000 MILES). *b*, AT 10H. 58M HEIGHT, 281,000 MILES). (FIGS. 10 AND 11 ARE REPRODUCED ON THE SAME SCALE.)

very numerous and again, as at present, are absent from the sun's disk for weeks together. But enough has already been told to indicate some of the chief characteristics of this central star of the solar system, which has thousands of counterparts among other stars of the same spectral class.

We are now approaching the last chapters in the life history of a star. After the solar stage has passed the color changes from yellow to orange, and subsequently to red, as the temperature falls. The spectral lines of hydrogen become fainter and fainter and finally disappear completely. The lines of the metallic elements, on the contrary, become more and more complex and the changes in their relative intensities are those which are characteristic of lower temperatures. But curiously enough,

there are two well-defined classes of these older stars, which until recently were not known to have any points in common except their red color. These are the stars of Secchi's third and fourth types. In general appearance their spectra are wholly unlike, particularly on account of the absence from third class spectra of the broad dark bands due to the absorption of carbon vapor, the most characteristic feature of the fourth type. But in spite of this apparent dissimilarity, photographs recently taken with the 40-inch Yerkes telescope show that in certain regions of the spectrum stars of the two types are practically identical and are thus probably more closely related than formerly appeared to be the

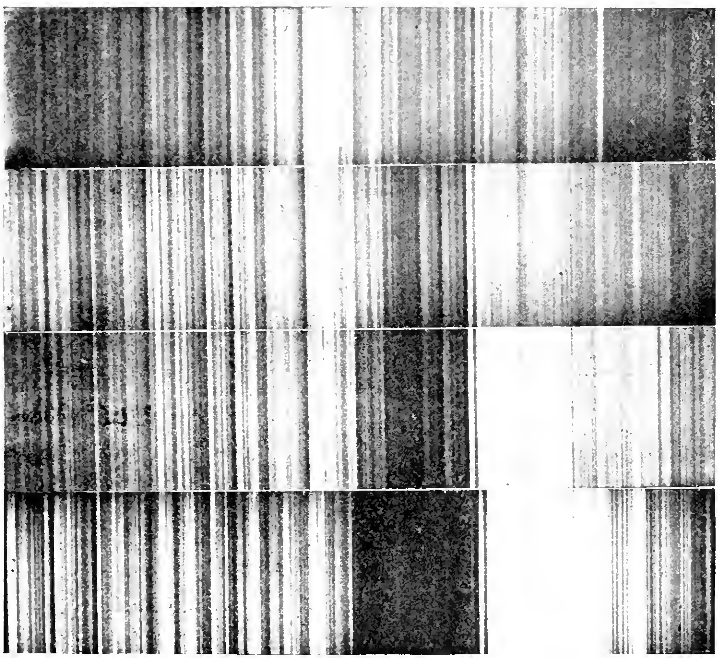


FIG. 12.

SPECTRA OF FOUR RED STARS (HALE AND ELLERMAN). SHOWING HOW THE DARK BAND DUE TO CARBON INCREASES IN INTENSITY AS THE STAR COOLS.

case. The measurements and reductions of a long series of photographs of fourth type spectra now in progress at the Yerkes Observatory should soon permit us to form an opinion of the nature of these interesting stars.

In both the third and fourth types it is easy to trace the successive stages of development. In stars of the fourth type the signs of increasing age are particularly striking. The carbon vapor which produces the broad dark bands becomes denser and denser, until it is not difficult to imagine that through the further increase of such absorption the light of the star might be completely extinguished (Fig. 12).

The phenomena of the red stars indicate that this final stage is close at hand, and curiously enough, in further testimony of the remarkable power of the spectroscope, the total extinction of a star's light does not always prove sufficient to place that star beyond the reach of this instrument. It is true that a spectroscope cannot reveal the chemical composition of a solid body which is devoid of intrinsic light, but such a body may form a system with another object which is still luminous, and its gravitational power may cause the luminous body to move in an orbit. As we have already seen, the spectroscope is capable of revealing the motions of such a body. From a knowledge of these motions and the time in which the revolution is effected it is possible to determine the mass and dimensions of the system, and in some special cases like that of Algol, the diameter and density of the invisible component of the pair.

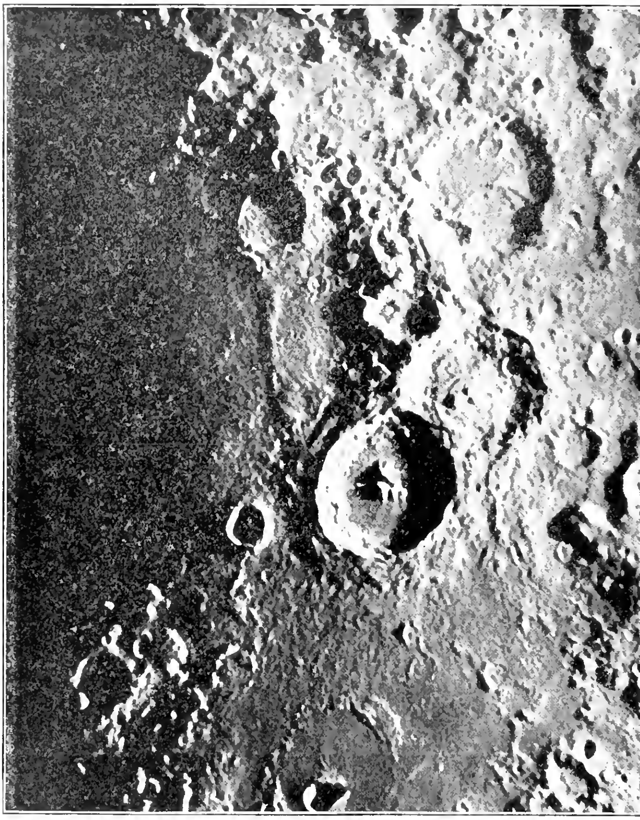


FIG. 13.
LUNAR CRATER THEOPHILUS AND SURROUNDING REGION. PHOTOGRAPHED WITH THE FORTY-INCH YERKES TELESCOPE (RITCHEY).

We must look to the solar system for examples of stars in the last stage of development. Each of the planets may in fact be regarded as an object of this kind. The bare and rocky surface of the moon affords a desolate picture of what may result from this long continued process of condensation. The volcanic region which is shown to excellent advantage in a photograph recently taken with the Yerkes telescope, (Fig. 13) gives no evidence of the existence of life; in fact, the spectroscope indicates that if there is any air on the moon it is much too rare to support life as we know it.

Fortunately, the moon is not the only example of a worn-out star. The earth, which probably has many counterparts in the universe, is another example of a less desolate kind. Here, though the process of condensation which is the chief cause of celestial phenomena has ceased, the problem of evolution has not ended. In fact, though the cosmical problems which we have considered in their barest elements will not be completely solved for centuries, it may be truly said that the questions raised by the countless living organisms in a single drop of ditch water are still more complex, and will require a still longer time for their solution.

WINGED REPTILES.

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OF the cold-blooded, air-breathing animals known as true reptiles there are now in existence upon the globe more than four thousand species, classified by naturalists in four very distinct groups or orders—the Rhynchocephalia, Crocodilia, Chelonia and Squamata. Of the Rhynchocephalia, there is but a single species now living, the Tuatera or Sphenodon, confined to the islands off the northeast of New Zealand, and very rare. It is a small animal, seldom attaining a length of twenty inches, lizard-like in habits and appearance. Though now so near extinction, the order during Paleozoic times was an important one, both in size and variety. No older reptiles are known.

The Crocodilia, inclusive of the alligators and gavials (better garials) number at the present time scarcely twenty-five species, confined to tropical and subtropical shores of both the old and the new worlds. Of great size, cruel and sluggish in disposition, they seem to be a reminder of those times when size, rapacity and cruelty characterized their class on land, in the air and in the water. Though approaching extinction, these modern representatives of what was at one time a far more numerous and widely distributed order are the specialized descendants of an ancestral line scarcely less ancient than the rhynchocephalian. In form and size, and probably also in habits, the crocodilia have varied comparatively little throughout the greater part of their long period of existence upon the earth.

Were none of the Chelonians—the tortoises and turtles—now living, the extinct forms would appear to us among the most remarkable of vertebrate animals, so little interest do familiar things incite. Like the crocodilia and rhynchocephalia, they are among the oldest of reptiles; yet in number and variety at the present time they are inferior only to the lizards and snakes, and may truly be said, after the lapse of many millions of years, to be only now at or but recently past the zenith of their development. In the past there have been species perhaps twice or thrice as large as any now in existence—from the Bad Lands of Dakota there is known one sea-turtle twelve or more feet in expanse of shell, with a skull nearly as large as that of a horse—but in type of structure the very oldest that we know differed but slightly from some that are now living.

On the other hand, the Squamata (so called because of the scaly covering which characterizes them) are the most modern of all reptiles. They number now more than thirty-four hundred species, about equally divided between the lizards and snakes, the only modern representatives of the order. In the remote past so far as we can trace the broken line of descent, the ancestral forms had but a single conspicuous offset, the rapacious mosasaurs, which had, however, a comparatively brief existence. The lizards, like the snakes, probably go back little or no further than the Age of Mammals. They are, with few exceptions, terrestrial animals of small size and inoffensive habits; the largest living examples scarcely exceed six feet in length, though within the period of man's existence there have been lizards five or six times as long.

Snakes or serpents, the latest, and in many respects the most specialized, of all reptiles, have not yet reached the culmination of their development, a statement which perhaps may not be truthfully made of any other group of reptiles. Their geological history is insignificant and scanty. The venomous serpents especially present the latest modifications of reptilian structure, perhaps the very latest antecedent to the final extinction of the whole class.

No reptiles at the present time walk erect, as did many of the extinct kinds. Their progression is essentially a crawling one, their legs, when present, serving more for propulsion than support. The only exceptions to strictly arboreal, terrestrial or aquatic habits among living reptiles are found in the curious and beautiful little flying lizards, or 'flying dragons,' of the Malayan region. In these reptiles, the flattened body is provided with a broad, wing-like expansion of the skin of its sides, supported by the elongate, movable ribs, and capable of being folded up, fan-like. Similar membranous expansions are also found on the sides of the throat. By these means the creature, which lives for the most part among the tree tops, rarely descending to the ground, is capable of certain aerial movements, though not of true flight. In describing its habits a writer has said: "As the lizard lies in shade along the trunk of a tree, its colors at a distance appear like a mixture of brown and gray and render it scarcely distinguishable from the bark. There it remains with no sign of life, except the restless eyes, watching passing insects, which, suddenly expanding its wings, it seizes with a sometimes considerable, unerring leap." Their flight through the air is very swift, so swift that the expansion of the parachute-like membrane may almost escape notice. As in the flying fishes, flying lemurs and flying squirrels, there is not true flight—a power possessed by no living back-boned animals except birds and bats.

Altogether the direct antecedents of the reptiles now living, that is the crocodiles, turtles, lizards and snakes of the past, took no important part in the great Age of Reptiles. They have existed all these millions

of years, some of them at least, because of their comparative insignificance among their many powerful relatives. Of these relatives, the huge dinosaurs, the swimming ichthyosaurs, plesiosaurs and mosasaurs, and the flying ornithosaurs, with others scarcely less renowned in geological history, are known only from the scanty records of the rocks.

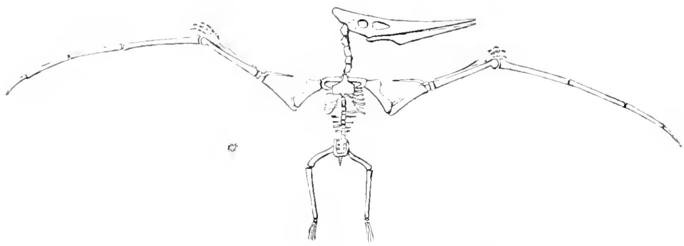
Of all the reptiles of the past, perhaps the most extraordinary, the ones which departed most from the reptilian type in form and habits, as well as the most highly specialized of all cold-blooded animals of the past or present, were the ornithosaurs or pterodactyls. They made their appearance in geological history, so far as is known, suddenly and in a highly developed state; we know nothing of their antecedents, nor indeed of their descendants. They flourished through millions of years in great numbers and multitudinous forms, and then, evidently, as suddenly disappeared. So different were these flying creatures from any others of the past or present that their proper place in the animal kingdom has been disputed. They were at first thought to be birds, and so described; and this idea of their relationship found expression in the name by which they are more properly known, the ornithosaurs or bird-reptiles. Some authorities would even yet give them a place all their own among animals, coordinate with the birds and reptiles. But they are now so well known to students of extinct life, and in so many forms, that there can scarcely be longer a serious question of their real, though highly modified, reptilian affinities. It is not impossible, however, though somewhat improbable, that they were, unlike others of their class, warm-blooded animals; it is at least highly probable that their circulatory and respiratory systems reached a much higher degree of perfection than is the case in any cold-blooded animals of the present time.

RESTORATION OF PTERANODON (ORNITHOSTOMA). EXPANSE OF WINGS, NINETEEN FEET, SIX INCHES.

As flying organisms they attained the highest degree of specialization that has ever been reached among animals with a back-bone, at least so far as their skeleton was concerned. Some of them, indeed, seem to have nearly lost all other powers of locomotion—they could move through the air only. Furthermore, the relative proportion between volant surface and body-weight in some of these pterodactyls has been

excelled only among insects. They were, *par excellence,* organisms of flight, to which function all else, so far as was compatible with existence, was subservient.

It was only among the later geological forms, however, that this flight specialization was carried to its extreme, a fact which has its parallel in not a few other classes of animals, where it has been only in

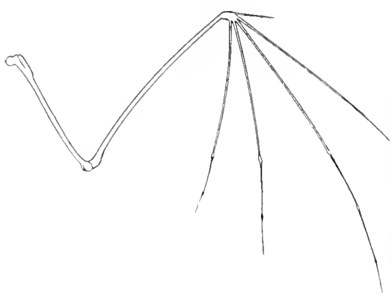


SKELETON OF PTERANODON (ORNITHOSTOMA).

the last bitter struggles for existence that the evolution of the type has been carried to its uttermost. In the accompanying figure is given a restoration of Pteranodon, one of these most highly specialized pterodactyls, based upon skeletons from the Cretaceous chalk of western Kansas. As in all restorations of extinct animals which departed widely from any now in existence, entire truthfulness of expression and appearance can not be expected. A more or less close approximation to the living picture is, however, assured from a complete knowledge of the skeleton and the impression in the rocks of form and of membranes, which have been preserved with the bones of allied forms. I use the more widely known name Pteranodon for this animal, though I believe it to be identical with the European genus previously called Ornithostoma.

The body of Pteranodon was short and relatively small; the legs were slender and weak, and loosely jointed; the toes were small and delicate, with little or no grasping power, and without claws; the tail was rudimentary. As if in compensation for the greatly reduced posterior part of the body, the whole anterior part—the head, neck, thorax and anterior limbs—was extraordinarily developed. The head was slender and elongate, with a dagger-like beak, possibly covered with a horny sheath, and the jaws were wholly toothless. In the largest species the head measured over four feet in length, and its equilibrium was maintained by a strange prolongation backward of the skull. The nostrils were placed far back, and the eyes were protected by a ring of bony plates, similar to those of the eyes of hawks and owls. The neck was long and strong, and very flexible, with a remarkable series of additional articulations unlike anything found in the neck bones of other animals, whereby the thrusting and striking power of the beak was greatly intensified.

But it was in the fore limbs and their attachments that the remarkable adaptation for flight of these animals is found. The shoulder-blade and coracoid, functionally replacing the collar-bone of many animals, were fused together into a stout curved bone, articulating in front with the broad breast-bone and behind with the spines of several fused back-bones or vertebrae. These two shoulder bones thus formed a complete, stout ring, firmly attached in front and behind. Such a mode of articulation of these bones is found in no other animal. To add further to the strength and rigidity of the thorax, the strong upper ribs were not movably articulated, but coossified with the vertebrae. Altogether, the large and broad breast-bone, the complete shoulder-ring, the rigidly fixed upper ribs and the immovable vertebrae furnished a support for the attachment of the enormous wing and its necessary muscles that has no parallel for strength among other animals.



WING OF BAT.

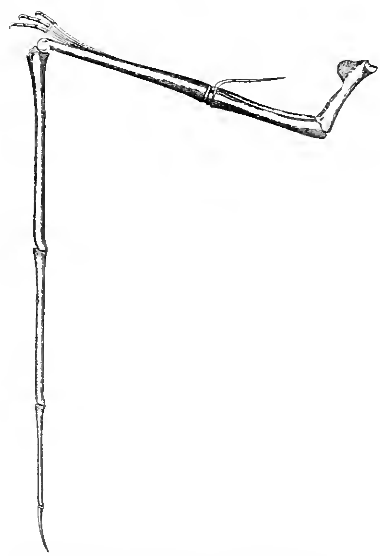
Among the higher animals there are three types of structure whereby the fore limbs are modified into organs of flight. In birds, the arm and fore-arm bones are elongated and strengthened; the bones of the wrist are fused together or wanting, while the few bones of the fingers are welded together and made to hinge sideways. In the bat, among mammals, all the bones, save those of the wrist, are elongated and slender. The very slender fingers are spread out fan-like laterally to support the membrane which replaces the feathers of the bird.

In the pterodactyls, the volant surface, as in the bats, was presented by a thin membrane, which extended from the fore limb to the sides of the body. The bones of the arm were strong, with strong projections for the attachment of muscles; those of the wrist were few in number and closely united. The rudimentary first finger, or thumb, consisting of a single slender bone, was turned backward toward the shoulder for the support of the membrane in front of the elbow. The second, third and fourth fingers were entire, but very small and slender, and were provided at their extremities with very sharp and strongly curved claws. While these fingers were flexible and prehensile, their small size and weakness of attachment (they did not articulate with the wrist) suggest that their only use was for clinging. In strange contrast with these small fingers, the fifth digit, that is the one corresponding to the little finger of the human hand, was enormously elongated and strong, including by far the largest bones of the entire skeleton. Between

its first and second bones there was a marvelously perfect pulley-like joint, permitting the flexion of the finger through an arc of nearly one hundred and eighty degrees. When not in use in support of the wing membrane, the finger could have been folded back close to the arm, touching each other nearly on the back. In fact these bones have been found fossilized in this position.

Attached to the whole length of the arm and finger to its curved extremity, there was a thin, and certainly strong, membrane, which continued on the sides of the body and legs, probably quite to the rudimentary feet. Impressions of this membrane have been found, showing every fold and crease, as though cast in plaster-of-paris.

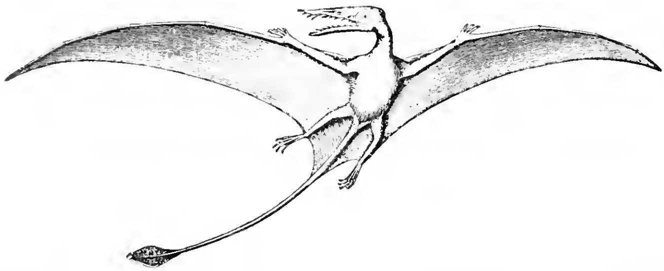
In size these highly specialized pterodactyls reached, as outspread in flight, the enormous expanse of more than nineteen feet from tip to tip of fingers. The length of the body from tip of bill to toes was about eight feet of which the head was nearly a half. Contemporaneous with these gigantic species were many others of smaller size, while related forms of an earlier period scarcely exceeded the stature of a common sparrow.



Anterior Extremity of Wing of Pteranodon, Nine Feet in Length.

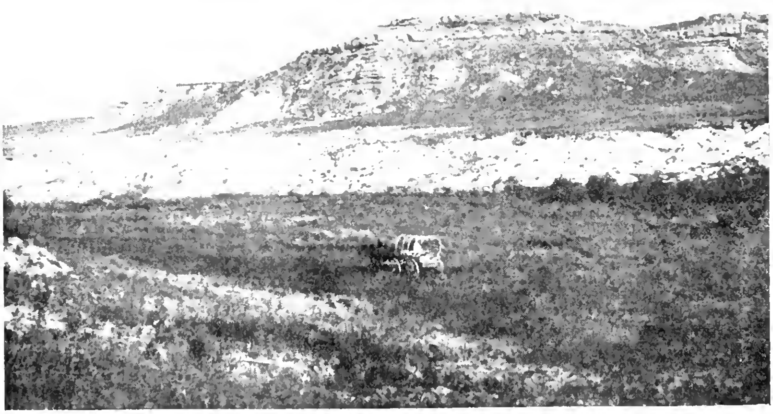
The earlier pterodactyls were smaller and in many other respects much less specialized than the latter ones, that is they departed less widely from the true reptilian type. Of these perhaps the best known is the Rhamphorhynchus, a restoration of which is given herewith, based upon a nearly complete skeleton in the Yale Museum, a specimen of great interest, because it shows so clearly the impressions of the wing membrane, wholly without hair, feathers or scales. In this pterodactyl, the jaws were provided with long and sharp teeth, the neck was less stout, the shoulders were loosely articulated, the bones of the wings less elongated, the legs stouter. Furthermore, it had a long, slender and flexible tail, provided at its extremity with a diamond-shaped membranous expansion, which doubtless served as a steering organ or rudder in flight. Between the Rhamphorhynchus and Pteranodon there were many intermediate forms, both large and small, with and without teeth. Species of Ornithocheirus, nearly as large as those of Pteranodon, which they closely resembled, except in the presence

of teeth, are known from the chalk of England. Rhamphorhynchus and the still earlier Dimorphodon, as well as the later Pterodactylus are from the Jurassic deposits of England.



Restoration of Rhamphorhynchus. One-eighth Natural Size After Marsh.

That the Pteranodon had a marvelous capacity for flight, there can be hardly a question. Their remains are often found in the Kansas marine chalk deposits associated with others of deep-sea animals, and many miles away from the ancient shore lines; found so completely preserved that they never could have drifted far. With their remains have been found the fossilized stomach contents, including comminuted fish bones and scales. The bones of their skeletons were



View of Cretaceous Chalk Deposits of Western Kansas.

very hollow and light, perhaps more so than in any other animals that have ever lived; so light indeed that a finger bone twenty-six inches in length might be best likened to a hollow cylinder of blotting paper

two inches in diameter; and this hollowness extended into nearly every bone of the skeleton, from the toes to the ribs and the skull. Moreover, the bones were all of fine and firm texture, and the sutures or immovable joints throughout the body were fused or anchylosed, as is the case with birds, thus giving the maximum of strength with the minimum of weight. The larger bones had each one or two pneumatic openings in them, through which doubtless entered ramifications of the bronchial tubes, as in birds.

Altogether the weight of a Pteranodon of the largest size in life could scarcely have reached twenty-five pounds—the bones of the skeleton having an expanse of twenty feet, even as petrified, do not weigh more than five or six pounds. This extreme lightness, together with the vast expansion of the volant membranes, suggests as a comparison the hull and sails of a Columbia or Shamrock. With the perfect and delicate construction and their strong articulations, the fusion of all loose bones, the presence of sclerotic plates in the eyes giving greater control over vision in high altitudes and in the dark, the possession of a relatively large and bird-like brain, all conclusively demonstrate the flight powers of these singular reptiles.

Upon land even the best of the pterodactyls must have been awkward and ungainly, creeping about upon hands and feet, impeded by the cumbersome head and flapping membranes. It is doubtful, indeed, whether the more highly specialized forms like Pteranodon often voluntarily sought the surface of the ground; they doubtless spent the most of the time while not flying, suspended from cliffs and trees by means of their slender, clawed fingers. In the air they reigned supreme and alone, save for the small toothed birds which were then making their appearance in geological history, and which may often have served as delicious tid-bits for their insatiable maws. The sharp, dagger-like beak, driven by the powerful neck, was certainly a murderous weapon against their enemies, whether upon land or in the air. That they laid eggs, like most reptiles, is almost certain. Did they build nests in inaccessible heights?

That the ornithosaurs for a long time enjoyed a wide distribution throughout the world is certain—their remains have been discovered in the most remote parts of the earth, and wherever the conditions were favorable for their existence and the rocks for the representation of their remains, traces of them may be confidently expected to be found. In North America, with a single exception, their fossilized bones have been discovered only in the Cretaceous deposits of western Kansas. Throughout this region there are wide exposures of pure chalk, the sediment of the old Cretaceous ocean, which at one time extended from the Gulf of Mexico to the Arctic Ocean, and from central Kansas on the east to far into Colorado on the west. Because of the pro-

tected situation of this inland body of salt water, and its placid surface, it was a favorite region for countless and divers animals of strange aspect. The waters swarmed with swimming reptiles of unfamiliar shapes and great size, while over its surface hovered and soared innumerable pterodactyls searching for their prey in the waters beneath. The delicate bones of the pterodactyls, beneath the pressure of the superincumbent rocks, have been, almost invariably, crushed flat, requiring skill and care in their excavation. Sometimes, though rarely, has a skeleton been found nearly complete; more frequently are the scattered bones found here and there. Considering the great buoyancy of their bodies floating upon the surface of the water, or sinking slowly through the ocean's depths, swarming as it was with many predaceous scavengers, one can only wonder that so many have been preserved all these millions of years for the delight and amazement of the modern student of geology.

THE JOURNEYINGS OF BIRDS.

By F. H. KNOWLTON, Ph.D.,
U. S. NATIONAL MUSEUM.

THE sudden appearance of certain familiar birds in spring and their disappearance at the close of summer has excited the attention and interest of all classes of observers from the earliest times. "The stork in the heaven," says the prophet Jeremiah, "knoweth her appointed time; and the turtle and the crane, and the swallow observe the time of their coming." Much curious speculation has been indulged in to account for this periodic appearance and disappearance, one ingenious writer of the early part of the eighteenth century arguing that when the birds leave in the fall they retire to the moon. He presumed that they required about two months in passing thither, and that, after arriving above the lower regions of the air they will have no occasion for food. Concerning the great distance, he adds, 'between the moon and the earth, if any shall still remain unsatisfied, I leave only this to his consideration, whether there may not be some concrete bodies at much less distance than the moon, which may be the recesses of these creatures, and serve for little else but their entertainment,' just as the rocky islands of the sea which he says are 'of no other manifest use than for sea fowl to rest and breed upon!'

Hardly less absurd but wonderfully more persistent has been the notion that birds hibernate during the winter in hollow trees, caves and holes, and, at least in the case of swallows, in the mud at the bottoms of lakes and ponds. Linnæus and Cuvier, as well as a great number of lesser lights, believed that swallows spent the winter in a torpid state in mud, and even as late as 1878, a writer in a prominent natural history journal in this country described the finding, in midwinter, of two swallows in the mud at the bottom of a spring in a logging camp in Maine. When taken out they are said to have revived and to have flown about in a warm room.

These absurd ideas have gradually given way to more rational views, and at the present time the whereabouts of a great majority of our birds is known accurately for the entire year. Their coming and going on these long journeys has been under intelligent, though often desultory, observation for more than a century and, although we have learned much, it seems likely that we are hardly advanced beyond the borderland of this intricate and fascinating subject. The object of the present paper is to bring together some of the more important

and striking of recent results for the purpose of showing that progress, although slow, is actually being made, and also in the hope that it may lead to further observation and record, for which there is undoubtedly abundant need.

In the first place, it may be well to define briefly certain phases of bird movement that are often overlooked or confounded with the generally accepted understanding of what migration covers. In the popular mind, and, it may be added, this is the correct view, a migratory species is one that regularly resorts to a given locality for the purpose of rearing its young, after which both old and young retire to some other, often widely different locality, where they pass the time before the next breeding season. In all temperate countries the migratory birds may be separated along these lines into two classes: first, those which come in spring, spend the summer and retire towards autumn; and second, those which pass through in spring to a breeding ground nearer the pole, and in the fall while on their journey south. The distinction between these two classes is obviously one of degree rather than kind.

The birds that come to us only in winter, such as Juncos, snowflakes, redpolls and Lapland longspurs, are not usually thought of as migrants, yet it requires but a moment's reflection to show that they are strictly so, and this leads to the general proposition that most birds throughout the world are constantly changing their location, but, as the individual is merged in the species, it is often difficult to obtain exact data on the subject. Because we see individuals of a certain species constantly about us, we call that a resident species, but, as a matter of fact, it is more than likely that not the same individuals are continuously under observation.

There is also another class known as occasional visitors, as the pine grosbeak and snowy owl, which may be absent for years, then of a sudden appear in great numbers. Their coming is supposed to be the result of a deficient food supply in their natural habitat far to the north, but the evidence for this is theoretical rather than actual. Hardly to be distinguished from these occasional visitants are the sudden incursions of species in a locality in which they have never been before known, as when a vast horde of nutcrackers spread over all Europe in 1844, or the erratic sand grouse, a bird of Central Asia, which has penetrated to England. But the climax of this restless and roving tendency in birds is reached in the stragglers that now and then are found hundreds, even thousands, of miles away from their homes, as when the Old World skylark is found in Greenland and the Bermudas, the American black-billed cuckoo in Italy, and our catbird and brown thrasher in Europe. While it may not be quite logical to class all these bird movements under the head of migration, as nar-

rowly defined, they are more or less clearly manifestations of the same influences and go to make up the sum total of this wonderful ebb and flow of bird life.

The origin, or perhaps better the origins, of this habit or instinct of bird migration is exceedingly obscure. Many theories have been advanced to account for it, but perhaps none has yet been offered that explains satisfactorily all its multitudinous phases. For instance, it has been suggested that migration is the result of the development or acquirement of the power of flight. That flight has had much to do in making long extended migrations easily possible no one can deny, but that it has been the cause is not logically evident, for certain mammals, as the bison and antelope, are to a limited extent migratory, and certain flightless birds, as the penguins and the great auks, are strictly so, or rather were in the case of the latter species which is now extinct.

According to Mr. F. M. Chapman ('Bird Studies with a Camera,' p. 194) 'the desire for seclusion during the breeding season' is a 'good and sufficient cause for the origin of bird migration.' He applies this theory especially to birds nesting in colonies in secluded spots, as the Ipswich sparrow which is known to nest only on Sable Island, off the Nova Scotia coast, the gannets (*Sula bassana*), which nest in the western hemisphere only on three islets in the Gulf of St. Lawrence, terns on Muskeget and Penikese, and the brown pelicans of the Indian River region of eastern Florida.

This theory may afford an explanation for the migrations of birds that congregate in such colonies during the breeding season, but it should not be overlooked that 'survival of the fittest' may have been an equally important factor in weeding out those individuals of such colonies that did not seek these secluded or isolated localities for breeding sites. These birds may at first have nested in scattered situations and have been driven by predatory animals or other causes to seek inaccessible locations, and seclusion and isolation may thus have been a resultant rather than a cause. It is also difficult to apply this theory to land birds. Take, for example, the warblers of the genus *Dendroica.* Some species barely reach the United States during the nesting season; a few stop in the southern tier of states; others only reach to southern New England, while the bulk of the species press on from northern New England to Hudson's Bay. If seclusion were the only point aimed at, it would seem that the warblers which pass farthest north to breed could have found it in the mountains of the southern and middle states as some now do. Again, certain species, as the cliff and barn swallows, phœbe and summer warbler, seek the vicinity of human habitations during the nesting season, and, moreover, have greatly increased in numbers since the country became thickly settled.

The theory that is, perhaps, most naturally suggested, and the one that finds widest acceptance as explaining the facts is that migration began in a search for food. That is, the food supply becoming short in the vicinity of the home (a bird's home is thus assumed to be the place where it rears its young, and may therefore be quite different from the locality where it spends the remainder of the time) they wandered away in search of food, returning again and again to the home vicinity. These journeys were extended farther and farther, the birds returning each nesting season, undoubtedly oftener at first, to or near the locality where they were born. This process went on until their wandering became a fixed habit, and finally in the countless generations of birds that have come and gone, this habit has been crystallized into what we now call, for want of a better term, the instinct of migration.

This idea has been amplified and extended by Alfred Russell Wallace ('Nature,' X., p. 459). He supposed that 'survival of the fittest' has probably exerted a powerful influence in weeding out certain individuals. He supposed further that breeding can only be safely accomplished as a rule in a given area, and that during a greater part of the rest of the year sufficient food cannot be obtained in that area. "It will follow that those birds which do not leave the breeding area at the proper season will suffer, and ultimately become extinct; which will also be the fate of those which do not leave the feeding area at the proper time." His further argument is ingenious, and, it must be added, extremely plausible. He says: "Now, if we suppose that the two areas were (for some remote ancestor of the existing species) coincident, but by geological and climatic changes gradually diverted from each other, we can easily understand how the habit of incipient and partial migration at the proper seasons would at last become hereditary, and so fixed as to be what we term an instinct."

It will probably be found, however, if anything like a satisfactory explanation can be arrived at, that this habit or instinct has arisen in more than one way, but we may appropriately turn from a consideration of theories to a review of certain observed facts of migration.

It is now abundantly established that migration is mostly carried on at night, and further mainly during clear nights. Only a comparatively few species, such as ducks, cranes, certain large hawks, swallows, swifts, and nighthawks, migrate during the daytime, and these it will be observed, are either rapacious birds or mainly those that enjoy such power of rapid flight as to be relatively safe from capture. All the vast horde of warblers, sparrows, finches, flycatchers, thrushes and woodpeckers, as well as many waders and swimmers, migrate at night. On clear, still nights during the migrations birds may often be heard calling to each other high over head, and, as will be described

later, may be actually seen by powerful telescopes. Woods and hedge-rows that were untenanted one day may become fairly alive with birds at daylight the next morning, showing that they have arrived during the night. They remain to feed and rest during the day, and, if the weather be favorable, may practically all disappear the next night. That they only venture on these journeys during clear nights is shown by the fact that on such nights very few birds are killed by lighthouses, monuments or other obstructions, whereas on cloudy or rainy nights, especially such as opened clear and later become over-cast, thousands of birds become confused and dash themselves against these obstructions. Thus over 1,500 birds have been found dead at the base of the Bartholdi statue in New York harbor in a single morning, and 230 birds of one species—black-poll warblers—were killed in a single night (Sept. 30, 1883) by the Fire Island light. The Washington monument, although not illuminated at night, causes the death of hundreds of birds annually.

The height above the earth at which migrating birds travel has been made the subject of some interesting observations, the first of which appear to have been by Mr. W. E. D. Scott, on the night of October 19, 1880, at Princeton, New Jersey. In company with a number of visitors he was being shown through the astronomical observatory at that place, and after looking at a number of objects through the 9½-inch equatorial, they were shown the moon, then a few days past its full phase. His attention was at once arrested by numbers of small birds that could be more or less plainly seen passing across the field of observation. Most of the kinds seen were the smaller land birds, among which were plainly recognized warblers, finches, woodpeckers and black-birds. He was able to identify with much certainty the characteristic undulating flight of the goldfinch, and the broad boat-shaped tail of the purple grackle. The flight of the birds noted was apparently nearly at right angles to the field of observation, and they were passing at the rate of 4½ per minute. As nearly as could be estimated their height above the earth was between one and two miles.

In the following year similar observations were made by Scott and Dr. J. A. Allen, but the results were not as striking, only 13 birds passing in any quarter of an hour. They were also apparently flying lower than on the first occasion.

Some years later observations on nocturnal flight were taken up by Mr. Chapman, who spent three hours on the night of September 3, 1887, at Tenafly, New Jersey. During this time 362 birds passed across the moon's face. Of these 233 were computed to be at a height of from 1,500 to 15,100 feet, and curiously the lowest birds seemed to be flying upward, as though they 'had arisen in the immediate

neighborhood and were seeking the proper elevation at which to continue their flight, but after that time the line of flight was parallel to the earth's surface.' He was able to identify positively only comparatively few species, such as the Carolina rail, grackle and a large snipe.

But perhaps the most satisfactory observations of all were those made also by Chapman, who, in company with a number of ornithologists, spent the night of September 26, 1891, at the Bartholdi Statue, New York. The weather proved to be exceptionably favorable, being clear during the early and later portions of the night, with an intermittent rain storm lasting for three hours between. As early as eight o'clock the birds began to be seen and heard, but almost simultaneously with the beginning of the rain there occurred a very marked increase in the number of birds seen about the light. They came singly, in troops, and in thousands, were visible for a moment and passed on into the darkness beyond. "The birds chirped and called incessantly. Frequently, when few could be seen, hundreds were heard passing in the darkness; the air was filled with the lisping notes of warblers, and the mellow whistle of thrushes and at no time during the night was there perfect silence."

The latest recorded observations were made by Mr. O. G. Libby ('Auk,' XVI., 140), who studied the nocturnal migrations at Madison, Wisconsin, in September, 1897. His first place of observation was a small elevation in the vicinity of three small lakes, where he undertook to make a record of the number of bird calls heard. During the night a total of 3,800 calls were recorded. The number of calls varied greatly, sometimes running as high as two or three per second and again falling to that number per minute. The largest number counted was 936.

From the nature of the data it was manifestly impossible to estimate the number of birds represented by these calls, but the effect was impressive in the extreme. He says: "Nothing but an actual experience of a similar nature can adequately convey the impression produced by such observations. The air seemed at times fairly alive with invisible birds as the calls rang out now faintly and far away, now sharply and near at hand. All varieties of bird calls came sounding out of the darkness that evening. The harsh squawk of a water bird would be followed by the musical *chink* of the bobolink. The fine, shrill notes of the smaller sparrows and warblers were heard only close at hand, but the louder ones came from all along the line, east and west. More than once an entire flock, distinct by the variety of their calls, came into range and passed out of hearing, keeping up their regular formation with the precision of a rapidly moving, but orderly body of horsemen. The great space of air above swarmed with life.

Singly or in groups, large and small, or more seldom in a great throng, the hurrying myriads pressed southward."

The second station chosen by Mr. Libby was the Washburn Observatory, where for three nights he watched the birds passing across the face of the moon. During the three nights a total of 583 birds were counted, the largest number in any fifteen-minute period being 45. Considerable diversity in the direction of flight was noted. Thus up to ten o'clock the prevailing direction was south, but after this time the diversity increased, until it reached its maximum between twelve and two o'clock, when eight principal points of the compass were represented by numbers varying from 3 to 28. However, two-thirds of the number were still maintaining a southerly direction.

Libby attempted to estimate roughly the total number of birds that passed his point of observation during the three nights, but as he well says, 'when one recalls the relatively small size of the moon's surface as compared to its path from east to west, within the range of vision,' the difficulty becomes evident. As nearly as could be made out about 9,000 birds were passing per hour or a grand total of 168,000.

The rate of speed at which birds travel during the migrations, and also at other times, has been made the subject of observation, although the results, as might be expected from the confusing elements which must enter into such an inquiry, are far from complete or satisfactory. If the speed often attained by powerful and swift-flying species, such as ducks, geese, swallows, etc., could be maintained, it is obvious that the time occupied in migrations would be inconsiderable. But, as will be shown later, the maximum speed appears to be rarely or never realized at this time.

Frank Forrester records 90 miles an hour for ducks, as noted by telegraph from point to point, and an albatross has been known to cover 3,150 miles in 12 days. The actual distance flown by the latter bird was probably at least twice as great, for they rarely fly far in a straight line.

Some years ago Griffitt made some observations (recorded in 'The Field,' Feb. 19, 1887) in a closed gallery on the speed attained by 'blue-rock' pigeons and English pheasants and partridges. The two first mentioned flew at the rate of only 32.8 miles per hour, while the partridge made but 28.4 miles, and these rates were all considerably in excess of what they made in the open. The carrier pigeon is a rather fast flying bird, yet the average speed is not very great. Thus the average made in 18 matches ('The Field,' Jan. 22, 1887) was only 36 English miles an hour, although in two of these trials a speed of about 55 miles was maintained for 4 successive hours. In this country the average racing speed is apparently about 35 miles an hour, although a few exceptionally rapid birds have made short distance flight at the

rate of from 45 to 52 miles an hour. The longest recorded flight of a carrier pigeon was from Pensacola, Florida, to Fall River, Mass., an air-line distance of 1,183 miles, made in 15½ days or only about 76 miles a day.

Herr Gätke, whose observations on Heligoland, a small island in the North Sea, extended over a period of fifty years, would give to birds a speed that is incredible. For example, the gray crows were believed by him to pass over the 360 miles between Heligoland and Lincolnshire at a rate of 120 miles an hour, and curlews, godwits and plovers are said by him to cross from Heligoland to the oyster beds lying to the eastward, a distance of a little more than 4 miles, in one minute, or at the astonishing rate of 240 miles an hour. The error in these observations, as suggested by Newton ('Dictionary of Birds,' p. 566), probably lies in the impossibility of identifying the individuals that leave one of the given points with those first arriving at the other end of the line. Professor Newton also calls attention to the fact that few birds, even swallows and quail, fly as fast as an express train from whose windows they may be observed. It is a common experience, when a train is passing along at no great speed, for various birds to be flushed by it, but after flying vigorously for a few hundred yards they quickly drop behind.

But granting that the occasional speed is very considerable, the actual speed of most migrating birds appears to be surprisingly low. Observations tending to prove this were made some years ago under the direction of Prof. W. W. Cook, in the Mississippi Valley. The services of over one hundred observers were enlisted, at stations ranging from the Gulf to Manitoba. The date at which a certain species was first noted at the most southern point was compared with the first appearance of that species at the most northern point; the distance in miles between these two stations is then divided by the number of days between the observations. Thus the Baltimore oriole was first seen at Rodney, Mississippi, April 7, and was not observed at Oak Point, Manitoba, until May 25. The distance in a straight line between these two places is 1,298 miles and as it took 48 days the average speed was 27 miles a day. The records of fifty-eight species for the spring of 1883 gave an average speed of 23 miles a day for an average distance of 420 miles, while in the following year a slightly smaller number of species gave exactly the same average speed over an average distance of 861 miles. In the case of individual species the results were of much interest. Thus the robin, cowbird and yellowhammer traveled at an average speed of about 12 miles a day, while the average for the summer redbird, ruby-throated humming bird and night hawk was 28 miles a day. It is, however, necessary to take so many things into account in arriving at these conclusions that it is easy to see the possi-

bilities of error. For example, meteorological conditions play an important part during migrations, a rain storm or an unusually cold spell may retard progress for days. Even if the conditions are favorable, it is hardly probable that the same individuals migrate for more than a night or two without intermission, so that while the species may be making progress the individuals are alternating a night or two of travel with often several days of rest and recuperation. Again, it was found that most species traveled considerably faster during the latter part of the journey than during the first part. Thus six species showed an increase of 77 per cent. in speed for the northern half of their journey, and the same general result was obtained by calculating the average speed of twenty-five species separately for each of the different months in which migration is performed; the average for March being 19 miles, for April 23 miles and for May 26 miles a day. The species which are late migrants also move faster than those which start earlier and take more time about it.

The persistence with which birds cling to established lines of travel during the migrations is one of the most remarkable facts within the range of bird life, and this in not a few cases can only be interpreted in the light of past geological conditions. Thus certain species which breed in Europe and spend the winter in Africa now cross the Mediterranean at one of the widest points, a seemingly needless waste of energy. But soundings between these points have shown that the sea for much of the distance is relatively shallow, and that a moderate subsidence has changed what may have been narrowest to what is now one of the broadest points. This subsidence was undoubtedly slow and first resulted in the formation of a series of islands and lagoons, and the birds easily passed from one island to another, and even after the last bit of land had disappeared they still followed the old route established by their remote ancestors.

Many shore and water birds that spend the breeding season in and about the arctic circle to the north of Europe and Asia, follow lines of travel during their migrations that were undoubtedly established under past continental or oceanic conditions. Thus certain species take a circuitous route over what is now a wide expanse of open ocean, while others pass far inland through the Russian and Central European lowlands. Those of the first class are simply still following an ancient shoreline, and those of the second class the location of an inland shallow sea.

The Old World migratory quail (*Coturnix coturnix*) is one of the comparatively few migrants among the so-called game birds. During the migrations they wander far from places of their birth, reaching South Africa, Persia and India. The individuals inhabiting Great Britain, or at least a part of them, long ago established a migration

route in a southeasterly direction. When examples from Great Britain were introduced into New England, they adapted themselves readily to their new surroundings and reared young, but when the season for migration arrived the inherited tendency to go in a southeasterly direction asserted itself, and, according to Mr. Wm. Palmer, of the U. S. National Museum, they all passed out into the broad expanse of the Atlantic and were lost.

For several decades it has been noted that a few species of birds from Western Asia have been gradually extending their summer range into northern Scandinavia. When these species migrate, instead of going south through central Scandinavia or southwest along the coast line, as do the original Scandinavian residents, they turn back east to the point in Siberia whence they came, before turning southward to spend the winter on the borders of India.

Forty or more species of migratory birds occur as summer residents in the Yukon Basin, Alaska. Of these some fourteen species are Pacific coast birds. With a single exception they are all thought to reach the upper Yukon by crossing the Alaskan coast range of mountains. This exception, according to Mr. W. H. Osgood, of the U. S. Department of Agriculture, is the varied thrush (*Hesperocichla nævia*), which apparently reaches its summer home by going up the coast to the mouth of the Yukon, and thence following this river for almost 2,000 miles. Equally abundant with it in this summer home is the common snowbird (*Junco hyemalis*) of the eastern United States, which reaches the Yukon Basin by way of the Mississippi Valley.

Perhaps the longest straight-away flight made during the migrations is accomplished by certain shore and water birds, as the tattler (*Heteractitis incanus*), sanderling (*Calidris arenaria*), turnstone (*Arenaria interpres*), and the pintail and shoveler ducks, which nest in islands in the Bering Sea and spend the winter in the Fanning and Hawaiian groups, a distance of some 2,200 miles. As the shore birds above enumerated are probably unable to rest on the surface of the water, the entire distance must be accomplished in a single flight. It is difficult indeed to see how this line of migration could have been established. Following the analogy of the Old World species before mentioned whose path marks an ancient shore-line, we might presume that there was at one time a land connection, or at least a chain of islands between the Aleutian and Hawaiian groups, but on the contrary the depths of the Pacific are profound between these points, and there is not the slightest geological evidence on which to base a former land connection. When it is recalled how slight a deviation at the point of departure would suffice to throw them to the one side or the other of the Hawaiian islands the accomplishment is truly marvelous. In the absence of familiar landmarks and surrounded by a waste of

sky and water, they make their way with the precision of a rifle bullet, and it would seem at hardly less speed.

The plovers, sandpipers and kindred species take migratory journeys often of extraordinary length. Thus the American golden plover (*Charadrius dominicus*) breeds in Arctic America and migrates through the entire length of North and South America to its winter home in Patagonia. The little sanderling just mentioned is almost cosmopolitan in distribution, breeding in Arctic and sub-Arctic regions and migrating in the New World to Chile and Patagonia, a distance of eight thousand miles, and in the Old World along all the shores of Europe, Asia and Africa. The Bartramian sandpiper (*Bartramia longicauda*) nests from eastern North America to Nova Scotia and Alaska, and goes south in winter to southern South America. The solitary sandpiper (*Totanus solitarius*) breeds mainly to the north of the United States and winters as far south as Brazil and Peru. The buff-breasted sandpiper (*Tryngites subruficollis*) rears its young in the Yukon district of Alaska and from the interior of British Columbia to the Arctic coast, and journeys in winter well into South America. The turnstone (*Arenaria interpres*), a little shore bird about the size of the song thrush of Europe, is also cosmopolitan, breeding in high northern latitudes and at other times of the year being found along the coast of Europe, Asia, Africa, North America, South America to the Straits of Magellan, Australia and the Atlantic and Pacific islands. It is one of the species mentioned as making the wonderful flight from islands in the Bering Sea to the Hawaiian Islands.

The ducks form another interesting group, although their journeys during the migrations are not nearly as extended as the birds just mentioned. The larger number breed mainly to the north of the United States and many within the Arctic Circle. Certain species, as the eider duck, only come south in winter to the coast of northern Maine, others, as the old squaw, may reach the Potomac and the Ohio, while most of them, as the bald-pate, blue-winged teal, pin-tail, golden-eye, bufflehead, etc., visit Mexico, Guatemala, northern South America or the West Indies.

Certain of the familiar birds of lawn, hedgerow and field, for whose coming we watch so anxiously, may claim a moment's attention. The bobolink, so dear to the hearts of the residents of New England, makes his appearance in his summer home in May. By the last of July or the first part of August the young are reared, the old males have lost their bright dress, and with a musical *chink* as their only note, they start southward. In the region of the Chesapeake they begin to congregate in vast flocks, where they are known as reed-birds, but in a few weeks they pass on to the rice fields of the South to become the dreaded rice-bird. But by October the last one has disappeared, and

some by way of Cuba, others by way of Central America, where a few may linger, the main body presses onward beyond the Amazon into central and southeastern Brazil. On the return journey they reach the southern border of the United States in March and April.

The catbird is found in summer throughout the eastern United States and British Provinces, and in winter in the southern States, Cuba and Middle America to Panama. Our common robin is very erratic in habits of migration. Occasionally a few may winter in dense swamps as far north as southern Canada and Maine, but the majority spend the winter in the Southern States. The chimney swift is found in summer in eastern North America and thence north to Labrador and the fur countries. The winter is spent to the south of the United States. Cliff and barn swallows, which are found over nearly all North America in summer, may penetrate to Brazil, Paraguay and the West Indies in winter. The scarlet tanager passes the winter in the West Indies, Central America and northern South America, and the familiar indigo bird may go as far as Veragua.

The great group of warblers, of which some 70 species are found in the United States, has been mentioned before. They are all strongly migratory and mainly pass beyond our southern borders in winter, although a few individuals of a single species—the yellow-rumped warbler—have been known to winter on Cape Cod. Some of them visit the West Indies but the larger number, after rearing their young in the dense coniferous forests of the Hudson's Bay region or even in Alaska, spend the winter in Mexico, Central America or northern South America.

The sparrows as a group are also strictly migratory. Quite a number, such as the tree sparrow (*Spizellla monticola*), snowflake (*Plectrophenax hyperboreus*) and longer spur (*Calcarius lapponicus*) breed far to the north of the United States in Arctic districts, and come down in winter into the northern states or irregularly farther south. Many species which breed mainly north of the United States only go into the middle and southern states during the winter, while a few may reach the West Indies, Mexico, Central America or northern South America.

But after having described these migration routes and the wonderful journeys over continents and vast oceans, the mystery of mysteries —How is it possible for the birds to find their way so unerringly?— still remains without a wholly satisfactory answer. As in the case of theories propounded to account for the origin of migration, so numerous suggestions have been made to explain this wonderful faculty. Thus Dr. Von Middendorff, a distinguished naturalist who studied exhaustively the migrations in the Russian Empire, suggests that because all the spring movements in that country are toward the

magnetic pole, the migrating bird knows the location of this point and is enabled to direct its course accordingly. It is perhaps needless to say that this theory is not only unsupported by any serious facts but, as has been shown by Baird, is opposed to the facts of migration in North America.

If during the migrations the older and stronger birds always led the way, it might be said with plausibility that this faculty is due in large measure to experience, but here again the facts are either conflicting or directly opposed to such a view, for it seems to have been demonstrated with reasonable certainty that in Europe the young birds not only precede the old, during the fall movement, but often travel by a wholly different route. In this country, however, observations on this point are limited and authorities differ, but the tendency is to believe that the old birds do actually lead. Observation is much needed to settle this question.

In the case of birds migrating over land areas, sight is supposed by some to have an all-important function, especially when it is recalled that a bird two miles above the earth is surrounded by a horizon line of 90 miles on either side. As already shown, they have been observed at a height of three miles, which would easily keep them within sight of prominent landmarks, and would even permit them to cross considerable bodies of water without entirely losing themselves. That they depend to some extent on such landmarks to guide them on their course seems to be shown by the fact that they migrate mainly on clear nights and are obliged to seek the earth on the approach of cloudiness and storms. But in the case of birds migrating over hundreds or even thousands of miles of open water, vision must play an unimportant part. Möbius ('Das Ausland,' Aug., 1882) suggests that in such cases they may be guided by observing the roll of the waves, but while this may be true in a few instances, it cannot possibly be so in the majority of cases. We, therefore, seem inevitably led to the conclusion that birds are possessed of a 'sense of direction.' This 'homing' faculty or power of orientation which is, for example, so strongly developed in the carrier pigeon, is by no means unique among birds. It is possessed in a greater or less degree by many animals, by most savage races of men and, not infrequently by individuals among civilized races, more especially those accustomed to life away from centers of civilization, in forest and on plain—just how it is to be explained is difficult to say. Some would give it the dignity of a sixth sense and would fix its seat in the semi-circular canals of the ear.

ENVIRONMENT IN RELATION TO SEX IN HUMAN CULTURE.

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THERE is a sense in which human environments may be viewed in their relation to sex.

The greater part of the earth's surface was sterile to all primitive peoples, anterior to the times when the harnessing of physical forces, little by little, brought all lands and all waters under human dominion. The seas, the mountains, the frozen regions and the deserts were never traversed by savage man. In other areas the soil was so rich that dense forests and impenetrable pampas, with their dreadful solitudes and venomous animals and plants, served as a prohibitory wall against human occupation until the good offices of fire subdued them.

The remaining areas, of which we are now speaking, may be divided into the bisexual, the feminal and the virile. These natural homes of humanity have been characterized as culture areas, areas of characterization, ethnic provinces, *oikoumenoi,* and so on, either by reason of their having produced marked varieties of the genus homo, or because special forms of activities have been demanded and fostered in them. Each of them has been studied respecting its salubrity, its food supply, its materials for elevating industries, its distance from the highways of progress, its scenery and resources of every kind affecting the welfare of our species; but here it is designed to interrogate them regarding their treatment of men and women.

The term 'progress' means the perfecting of mental attributes and bodily skill of the individual and enlarging the number of persons cooperating in the same activity over longer time and greater space simultaneously.

The exigencies of maternity always differentiated the activities, the artistic creations, the language, the social life, the knowledge and the religious conceptions of women. Over and above all actions in common with men, they were spinners, dyers, weavers, nest-builders and purveyors. For them the fireside was literally the focus of innumerable cares.

In any mode of primitive life, on the other hand, men went to war with the elements and with things. In their hands was the apparatus of capture, of incarceration, of slaughter. They exploited the boundaries of the unknown in every direction.

The three kingdoms of nature—animal, vegetal and mineral—were the arena upon which men and women acted the drama of progress.

The animal kingdom.

The animal kingdom was, on the whole, in relation to human progress, the lowest of the three, inasmuch as less exalting artificiality has grown out of it for women as well as men, but more exalting for men than for women. The ever-increasing wariness and remoteness of the animal called for increase of cunning, skill and united effort in man. The apparatus had to be more ingenious and effective, the individual hunter more resourceful, and men had to be mobilized in larger numbers, for longer times and for greater distances.

When the hunter state gradually passed into the pastoral state, the same pedagogy went on, for the hunter now came to be the aggressor and defender in the care of his flocks, killing rapacious beasts and men; and the annual hunt, a marvel of temporary concerted action and intelligence, coming to be the permanent military organization.

Face to face with the animal kingdom, the zootechnic activities of women were of quite another sort. It was they who skinned and packed the game, cured the fish and converted the soft parts of animals into products for human comfort. In the slow processes by which the feral states of animals became domestication, women collected the young, often nursed them, attracted the adult. In those areas where she could best do this was her vantage ground.

In the pastoral state the muscular energies of beasts became the servants of men, lifting many burdens also from the backs of women. Herein came the saddle beast, the pack beast, the traction beast, the permanent supply for art and for sacrifice. As to woman, it brought to her door milk, flesh and wool.

The vegetal kingdom.

In contact with the vegetal kingdom men were the inventors of woodcraft and bark-craft. Women were primitive gardeners, gleaners, basket- and mat-makers, and spinners. Edge tools, therefore, were man's—ax, adz, chisel, whittling knife, all for wood-working; but carrying-baskets and spindles were women's. Sedentary village life is the product of the vegetal kingdom. In its earliest form it is woman's sphere. To plant the seed, to till the ground and to gather the crop were hers. What men did all this time was to guard the women and the crops and to develop a military, regulative government. The mound region of the Mississippi Valley is an eminent example of this, where the remains of ancient corn rows survive in the midst of forts and ceremonial earthworks.

The mineral kingdom.

The mineral kingdom did most to emancipate the fancy and develop the genius and strength of men through stone and metal; for women, its pedagogic efforts were through the pliant and versatile clay and the water springs. Find a region south of the line of severe cold where clay abounds, coupled with demand for sedentary life, there the ceramic art in primitive times was efflorescent. The clay and the woman gradually become refined and exalted. The qualities of the material were discovered and developed, the great possibilities of manual refinement and dexterity found a worthy arena. In later times Keramos came to be a man, because machinery supplanted the hand; but at first potters were women.

On the other hand, if you except the scraper and the household knife, in flakable, siliceous stone, the worker in stone was always a man. Piercing and slashing weapons had their points and edges worked by men. It is with admiration that we now look upon the products of knack and patience kept in museums as precious relics of the men of old. Wherever the best flint was known there the men were quite equal to play upon the material and to be played upon by it, the flint and the artist being mutually perfected.

But friable stone had in it even more for man than flint. The gem cutter, the sculptor, and the architect went to school to crystals, to calcareous and volcanic stone. The flaker was invented for flint, but the hammer, the bushing tool, the chisel, the rasp, the diamond drill, the saw, the emery wheel and engineering appliances were all devised by men at the invitation of art and architectural stones. In those areas where these last abound men were regenerated. A casual glance at the map of the Western Hemisphere shows that only where the engineer and the architect were called for was there aboriginally any approach to civilization.

The forces of nature.

Professor Rouleau, of Berlin, divides culture into phases which he calls 'manganic' and 'naturistic'; the former term applies to the use of machinery and the domestication of nature's forces, the latter to that condition of culture in which the hand was aided by the simplest appliances. On every grade of culture women were more naturistic than men. Any culture area, therefore, which afforded occasion and stimulus for the employment of mechanical powers, the forces of nature, and continuous organized effort of mind and muscle was virile and most propitious for men.

Nor are conditions of climate and daylight to be neglected in this connection. For men, progress was more difficult in uncongenial climes. Women had sheltered, indoor temperature artificialized in the frozen zone with the help of the lamp-stove. Hence all the enduring monu-

ments of early man's advancement are only within those temperate areas or elevations where neither heat nor cold was excessive, and where the food-quest was not exhausting.

Interesting here also is it to note the length of day in culture areas, especially for out-of-door men. The following table gives nearly enough the duration of the longest and of the shortest day for the different latitudes:

70° the sun is visible from May 16 to July 27.

60°	longest	sunlight,	18h. 53′,	shortest	sunlight,	5h. 52′
50°	"	"	16h. 23′,	"	"	8h. 4′
40°	"	"	15h. 1′,	"	"	9h. 20′
30°	"	"	14h. 5′,	"	"	10h. 13′
20°	"	"	13h. 20′,	"	"	10h. 55′
10°	"	"	12h. 43′,	"	"	11h. 32′

Culture areas of the New World.

The Western Hemisphere offers the best field for studying culture areas and primitive life in relation to sex. The two extremities furnish a striking contrast between a sterile and a bi-sexual area. In Fuegia, with climate like that of Labrador, the conditions of living are such that beyond merely holding their own there is little to uplift either men or women.

On the contrary, along the arctic border are the cunning Eskimo, living in an environment that is both virile and feminal; but it is solely zootechnic. There the women are housekeepers, tanners, clothiers and embroiderers.

The men have the sinew-backed bow, the retrieving harpoon, and the skin kaiak, in each of which you see the maximum result of skill with the minimum of material. During the long winter the æsthetic faculty was exercised in carving and etching upon hard animal tissues. The underground ceremonial house and the snow dome are models of construction. Dogs were traction beasts, rapid transit over snow and ice was installed; harness, sleds of uniform width, economic food and packing sharpened the wits. The boundaries of the environment rich in animal life seemed unlimited, so that many hundreds of miles of shore country were exploited by a people speaking the same language. Inland, about the Yukon drainage, women were among the most forlorn pack beasts and slaves on earth.

The birch-bark area.

Eastward from the Rockies and throughout Alaska is the birch-tree country, quite poorly furnished for men, far better for men than women. The snow-shoe is at home here, and also the birch-bark canoe. Here

throve fur-bearing creatures in great variety, coveted by the titled and fashionable in the Eastern Hemisphere. The trader brought along with him the gun and the curved knife, with which men built better canoes and women cut the finest leather, called babiche. Result: better boats for water travel, better snow-shoes for snow travel and also better men and women. But primarily, after all, conditions were hard and starvation was not unknown.

The sleds of the birch-canoe region have no runners; they are boats to move on the snow. In the fur trade the dog became exalted through external stimulus, and the voyageurs were known as the hardiest of men.

In the realm of the æsthetic, however, through all the birch bark area men knocked at the door of Nature in vain. The fine art of both sexes was in ephemeral costume decorated with porcupine quills. No pottery, basketry, woodwork, stonework, earthwork or fine carving of any kind existed. Since the art faculty and the materials are always exalted mutually, it is in vain to enquire whether the one or the other was lacking.

The north Atlantic area.

The drainage of the St. Lawrence, the Appalachian mountains, and the Atlantic slope together formed the culture area for two powerful Indian families, the Iroquoian and the Algonquian. The annual round of varied employments, in peace and in war, developed a fine breed of men. Cultivation of maize by the women, added to their zootechnic activities, trained their wits in economy and cooperation. They were not excellent potters or weavers, however, and their advancement was far behind that of the men. Matriarchy was breaking down at the period of the Discovery. The early records of these two families abound in accounts of long journeys, of masterful enterprises, of concerted activities, of imposing councils, of treaties and alliances, which go to show that the Atlantic slope long ago could produce noble men.

The Mississippi valley area.

Between the Blue Ridge mountains and the Rockies, when the historian arrived, two contending cultures had been at work, evoked by the kingdoms of nature—that of the buffalo and that of the prairie. As the land of Egypt is the residuum of a continuous warfare between the desert dust and the Nile floods, so the phenomenon of roving tribes living on the sites of mounds and earthworks, of which they had neither knowledge nor tradition, was the outcome of the conflict between the hunting Dakotans and their congeners on the one side and the agricultural builders of mounds from the south.

The Muskhogean area.

If the reader will examine Merriam's temperature charts in relation to zoological distribution, he will note that the color symbol of the southern states of the Union extends far to the westward. He will not be surprised to find that the Rocky mountains lowered their drawbridges in times past for the migration of ideas. The Muskhogean tribes built pyramidal mounds. They were sedentary. The men were tall and mentally vigorous. Their descendants, now in the Indian Territory, were capable of great enterprises. The women were skilful farmers, weavers and potters. The gulf province was bi-sexual.

The south Atlantic area.

Southeastward from the Muskhogean area lie the Antilles, the Orinoco basin, the Amazon basin, the Mato Grosso and the Pampas. In them men had little to do save to hunt and fish, to fight and to sleep in their hammocks. They were zootechnic, passing into phytotechnic. No great man was ever bred in such a school. The women were farmers, potters, tapa-makers, spinners and hammock-knitters, and there is ground for believing that in several portions of the area there were settlements made up wholly of women, or Amazons (Payne, Hist. of Amer., II, p. 11).

The men in the northern portion were also water craftsmen, and that evoked and trained their hand, their skill and their wits. The Caribs are said to have been the only American people who colonized by sea voyages. In art, men were carvers in wood and stone, attaining creditable skill in Puerto Rico and Guadeloupe. However, as in other areas, there was absence of solidarity. The women on the Orinoco, the Amazon and the Xingu made exquisite basketry and featherwork, and jewelry of teeth and seeds. They cultivated cassava and other plants, and their cabins were thronged with birds of gay plumage. So lacking was industrial stone in all this lowland that shell and teeth were the only materials, on which account Von den Steinen humorously proposes to speak of a bone and shell age of man.

The tribes of the pampas, before the coming of the horse, had a meager life. It is true that the guanaco and the rhea were at hand plentifully. But the men in association with such environment were not much more than clever panthers with long and sharp teeth called arrows and spears.

The women were much more cultivated, being excellent tanners and making rude pottery. Their houses were only shelters of skin and their art was limited to painting geometric patterns on robes. The two sexes were equally non-progressive, but being amply fed they grew in stature and were among the tallest Americans.

The north Pacific area.

On the Pacific slope of America, between 45° and 60° north, lies a well-marked culture area. The mountains near by and the ocean have between them innumerable islands, great and small. Passing among these was easy; the climate, by reason of warm currents in the sea, mild; animal and vegetable life useful to human existence, copious. There is no flint, but slate, nephrite and volcanic rocks of good quality. On this domain men traversed long distances in dugout canoes holding fifty persons, and artists expressed their mythic fancies through the obliging cedar wood. Had they lived thirty degrees farther south, these men would have been able to rival the builders of Nahuan and Mayan stone temples. For women, pliant roots and tough grasses fascinated their artistic spirits, resulting in exquisite twined basketry. As in all other island areas, however, the tendencies are centrifugal. The linguistic families were separated into innumerable *kwans,* or clans, without national solidarity. The southern boundary of this canoe culture province is the Columbia river, highway of tribes and patron of men. On this coast were matured commerce, slavery, a diversity of industries and a varied annual round. Material was afforded and leisure also for the unfolding of a complicated mythology and its embodiment in wood, stone and hard animal substances.

The Oregon-California area.

The next unique area lies on the Pacific slope, between 35° and 48° north, chiefly in Oregon and California. Upon this long strip facing the sunset was woman's paradise; it was at the same time 'No man's land.' The men there are among the shortest, and the height of the women is 94 per cent. of the men's. Twenty-four different stock-languages are spoken. It is not so much a single culture area as a series of cul-de-sacs, a *cloaca-gentium,* coves in the mountains opening out on the islandless, harborless, fathomless ocean. It is the Caucasus of the Western Hemisphere. You see there no huge canoes, no carvings in any material, no partnerships or great enterprises. The only redeeming virile feature is the yew bow with sinew back and the most delicate arrows on the continent.

But what a heritage in textile materials! Nowhere else on the globe was there such a variety of stitches in basketry and nowhere else were women's fingers so nimble in basket-making. There was no spindle, no loom, no pottery, but the basket served all purposes for the gleaner, the miller, the cook and the purveyor. The art sense, almost extinguished in the men, barring a little skill in shell and feathers, effloresced in woman's work, to the astonishment of the ethnologist.

The Pueblo area.

The plateau bounded by the Colorado and the Rio Grande was long the home of the clay and adobe worker. The men were short, and the height of the women in the pueblos was 93 per cent. of that of the men. Rabbits, mountain sheep, antelopes, coyotes, mountain lions, hawks and rattlesnakes were the useful and mythical animals. The vegetal kingdom furnished poor timber, but good textile fibers and a varied diet of corn, melons and beans. As in the Ohio valley, though in different materials, artificial food production was associated with defense. The cliff home and the pueblo solved the problem of architecture and fortifications in the best possible situations and materials.

The artificializing of this pueblo life can not be divorced from water culture and cult, woman's prerogative. In a region whose life is a perpetual sigh for water, the nymph and the potter are one. Women are pack beasts for clay; modelers, decorators, burners of pottery. The water seeker, carrier, storer, user, server, is the potter. The tempting foods set before the gods of the elements were served in baskets and vessels of clay. The feminal life of the pueblos, therefore, was higher than the virile, and it is so to-day. Cushing says that the men's efforts were concentrated on activities connected with maintenance and the worship going therewith. Most of the fine art, however, excepting the little painted dolls, in the service of religion, is feminal; it is on pottery and basketry, not on shields and manly costume.

The Mexican area.

At the genial southern extremity of the same plateau, reaching from Quimbawa, in Zacatecas, to Nicaragua, lie the Mexican uplands, man's best friend in all aboriginal North America, as the region about Quito was in South America—a climate whose daylight varied little throughout the year, whose temperature was so equable that food plants, like the trees of the Apocalypse, bore their fruit every month, a region whose elevation and proximity to the gulf and the ocean gave the largest yield of land and sea food for the smallest effort, especially, however, a region abounding in architectural stone in which men might fix their epics and their dreams, and in hard rock for stone cutters' tools.

Mean temperature of the City of Mexico.

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
75	80	80	79	75	69	69	66	63	66	70	73

Such a land was favorably situated for leisure, for organization, for unbroken cooperation in economic social and religious activities on a large scale and, proportionally, to develop the manliness of men. One

is not surprised, therefore, to find here in great profusion a summing up in stone, both in sculpture and architecture, of all the motives scattered in clay, wood, textile and feather-work over the northern continent. Here also are seen fully developed those virile art forms and decorations of which Cushing finds among the pueblos only vestiges on pottery and basketry. The high culture of the Mexican and the Mayan broke down in Honduras, Salvador and Nicaragua, where are even now found any number of unclassed, insignificant tribes.

The Colombian area.

The extension of the Cordilleras southward need not detain the reader. Stretching from Nicaragua to the southern limits of Colombia were the Muyscas or Chibchas, metallurgists and jewelers *par excellence.* It was in their country that Balboa heard of the great riches farther south. Theirs was the home of 'El hombre dorado,' or Eldorado, where, on the inauguration of a chief, a procession of men richly dressed marched to the borders of their sacred lake bearing him on a splendid litter. The chief's 'naked body had been anointed with resinous gums and covered with gold dust.' He was rowed to the middle of the lake and plunged himself in to wash the gold from his body as an offering, at the same time his followers casting in enormous quantities of gold and emeralds. (Bandelier, 1893, p. 14.)

The women were farmers, potters and weavers. They cultivated maize, beans, yucca and cotton. Irrigation was practiced, the ditches, no doubt, being the result of organized, far-reaching and long-continued labor among the men. The conditions for united effort in large architectural enterprises did not exist, but commerce in salt and gold was active. It was not until a widening of the area and a lengthening of roads farther south in the inter-Andean valley made larger aggregations of men feasible that the noblest of arts discloses itself again.

The Peruvian area.

The Quichuan, or Kechuan family, including the Aymaran, occupied a strip of upland two thousand miles long on the Pacific slope of South America, all parts of which were joined by trails. Here Indian men reached their zenith. The dissemination of their culture was conterminous with their speech. The foci of this virility were Quito and Cuzco. The architecture was rock-hewn and cyclopean, wrought with tools of stone. Agriculture had passed to the artificial conditions in which metallic tools were used, in which terraced gardening, irrigation, use of guano and grain storage were practiced. The llama and paca were bred in vast numbers for food, for textile material and for pack beasts. Metallurgists wrought skilfully in bronze, silver and gold.

Woman's work, some of which had passed on to the virile stage, was of the first rank in curiously-wrought pottery and in textiles made from paca wool, one of the finest staples, as their delicate spindle whorls will attest.

But these Peruvian uplands were the training grounds of men especially. Together the earth, the air, the waters, the tropical day, conspired to develop them. The sun was their chief deity, source of life and power, so their principal chiefs were its earthly viceregents. The barbarous and bloody rites of Mexico were absent, as were the graphic system and the pictorial literature. But the monuments of a departed glory remain.

Conclusion.

Did space permit, the Eastern Hemisphere might also be put upon the stand as to its treatment of men and women from area to area. It surely can not be an accident that, before artificialized transportation interrupted the ancient régime, centers of culture and refinement survived for millenniums. Pastoral regions, land-locked seas, rice fields, bamboo jungles, above all, granite and marble quarries, are even now surviving and drawing around them the same refined spirits as of old.

This recital would be without a moral if it did not also apply to the higher, manganic, complex environments in which civilized peoples are living. There are tendencies in some to degrade men, especially to take from them that spark of originality and self-reliance which is the source of virility, of progress, of family life, and to reduce them to intellectual and moral peonage. This, in ways not necessary to mention here, lowers the birth rate, doubles the death rate, degrades the survivors and destroys the state. From primitive times until now there never came any solid advancement to a people that had not something ennobling for men and women to crave, or that sacrificed them to any god or fetish whatsoever.

THE COLLEGE-MAN AS LEADER IN THE WORLD'S WORK.*

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IN the twentieth century the college-man is, more than ever before, the leader of the world. Mind leads the world; mind ultimately is the ruler of the world. That mind leads the world which is not simply developed into maximum intellectual perfection; it is that mind which, perfected and strengthened and given symmetry and vigor, is also made most thoroughly at one with the world. It is not enough that the man shall be a great scholar, or the greatest of scholars; nor is it enough that he shall represent the highest culture and possess the most vigorous brain; nor can learning, even learning united with wisdom and culture, however magnificent the whole, in union give leadership in this world.

A primary requisite of leadership is close and strong connection with the great world to be led. This union being assured the true leader gains and holds his leadership by the exercise, in unrivaled power and with unequaled tact and judgment, of those talents which have been reïnforced by the no less indispensable learning and culture and wisdom; these united confer leadership. Ultimately, also, it must be remembered that the greatest mind can never lead if apart from the world and out of touch with those who are to be led. Any man of good sense and rich in humanity, even though unlearned and without extraordinary genius, will sooner acquire leadership than the wisest and greatest man of genius the world at the time possesses, lacking this firm hold upon those who should follow.

He who would lead must have this compound constitution and must acquire the useful forms of learning and the hardly less valuable forms of culture, for such purposes, and he must cultivate that wisdom and tact and those virile qualities which are all-essential to perfect success. He who would lead must be prepared closely to follow leaders preceding him, and the requisites for following leaders in the front ranks are substantially the same, apart from the peculiar genius of the general of the army, as for leadership itself. And each should be well prepared to follow, each in his proper place, and there to be content while most efficient.

The twentieth century man will unite the qualities of sage and

* A Commencement Address, Case School of Applied Science.

worker and organizer and administrator as has no man before him. Uniting better than in earlier centuries the essentials of the perfect man, he is to do a larger and nobler share of that upbuilding of the nation which shall come with the realization of the prayer of the great American poet:*

> "Our fathers' God! From out whose hand
> The centuries fall like grains of sand.
>
> . . . .
>
> O! Make thou us, through centuries long,
> In peace secure, in justice strong!
> Around our gift of freedom draw
> The safeguards of our righteous law;
> And, cast in some diviner mould,
> Let the new cycle shame the old!"

A century ago there was but one recognized form and method of education—what is now termed the classical—composed of studies of the ancient languages and literatures, comparatively lean and narrow as they are; the elementary mathematics, to the extent now attained in the secondary schools; a homeopathic dose of physics and chemistry; a little French; and a somewhat larger, if less palatable dose, of 'philosophy.' The century has been one of extension, broadening, elevation, diversification and systematization of education, and of the incorporation into the curriculum of the modern languages and literatures; the modern physical sciences experimentally developed; the arts, fine and useful, so far as capable of scientific treatment; and the principles and practice of the professional schools, including the latest and most strictly taught of the group, the school of engineering and its associate professional schools of every sort. The whole evolution of the century has been consistent in every field and technical, 'practical,' education is simply one of the elements of a complete and perfect evolution of modern life.

The world now acknowledges its need of the college-man and my own letter files are crowded with calls for competent men far in excess of the number available; while the number seeking even improved situations is small, and I know of none out of work, unless ill. At the top, the space is enlarging, though it is always ample for tip-top men. Formerly positions paying five thousand dollars were rare, now the college-bred man is coming forward when ten-thousand-dollar positions are seeking, and failing to find, the men who are competent to fill them satisfactorily. Generals are, comparatively, still more rare than ever, even though training for generalship is going on at an unprecedented rate and the opportunities are multiplying for great men and good men and capable men as never before.

* Whittier.

And among the leaders of the world, nobly rivaling every other, stands the 'Captain of Industry,' now rapidly developing into general and field marshal. Note what this sort of man has done for the world!

The inventive mechanic and the engineer, learned or unlearned, have, in the course of the nineteenth century, given to the world the locomotive and our whole system of general continental and transcontinental transportation, the steamship and all our contemporary ocean and river, freight and passenger lines, the automobile and the beginnings of a new and still more widely helpful system of common highway transportation. They have given us the mowing and reaping machines which have reduced the time and cost of harvesting to a tenth and less of its former value; the seeding and the threshing machines which have done as much in their special fields; the sewing and the knitting machines which have given the sewing woman and the housewife multiplied working power with minimized exertion and reduced working hours. They have provided the power-printing press with its almost miraculous speed and accuracy of printing, counting, folding and binding together the sheets of a metropolitan newspaper 100,000 an hour; the type-setting machine and the linotype, making easy and productive in hardly less degree the labor of the type-setter; the whole machinery of modern textile manufacturers with its multiplied efficiency and the iron and steel industry, the fundamental element of civilization.

The electrician and the mechanical engineer have provided us with the electric current in useful and infinitely pliable form, transmitting energy of all mechanical prime motors from the source, or point of surrender of energy by nature, to the point of application, a mile, ten miles or a hundred miles away, with little loss and with vast convenience and economy. The engineer is even furnishing power for use in transmitting messages over the telegraph wire. In our homes, steam-heat, ventilation and sanitary life come largely of the inventions, the constructions and the operative mechanism of the engineer, who provides the steam-boiler, the water supply, the forced ventilation, all unknown to our fathers, luxuries to many still, but which will become the ordinary and commonplace comforts of the great mass of the people in the coming century.

The mechanic and the engineer have provided us with iron ships and naval armaments, the battle-ship and the torpedo-boat, the 'submarine,' and guns that have a range of ten to twenty miles. They are thus doing practically all that is actually being done, at the time—they have done practically all that has been done during the century—toward making an end of war by making weapons too effective to permit their use by nations except in desperation and under extreme provocation. Under such provocation, in the future as in the past, nations will probably make war; but it is the engineer, probably, who will

always prove the effective peacemaker, both by his tremendous power of making war costly of life and property and, especially, by his no less tremendous and vastly more admirable power of making the arts of peace the means of attaining a higher civilization, of advancing the interests of the people, of uniting all peoples in common interests and making political boundaries subordinate to the best interests of all.

Thus has the inventor and the mechanic provided the apparatus of production of a new world and converted by its use barbarism into civilization, light into darkness, developing in slave and drudge soul and intellect and humanity. But it is not enough that the apparatus should be provided; it must be placed in hands competent to use it effectively and the whole modern organization of industries constitutes the no less essential apparatus of utilization. Its armies of workers must be directed by officers of every grade, commissioned and non-commissioned, generals, colonels, majors, captains and lieutenants, sergeants and corporals. Without organization the armies of industry degenerate into mobs and threaten life and property and become entirely incompetent to keep in motion the machinery of production. Well organized, every invention finds its use and every people profits by its employment; production proceeds with increasing efficiency and the world grows comfortable and happiness becomes attainable.

Says Carlyle: "The Captains of Industry—happily the class who above all, or, at least, first of all, are wanted in this time. . . . It may truly be said, the Organisation of Labour (not organized by the mad methods tried hitherto) is the universal vital Problem of the World. . . . The few wise will have, by one method or another, to take command of the innumerable foolish; that they must all be got to take it; and that, in fact, since Wisdom, which means also Valour and heroic Nobleness, is alone strong in this world and one wise man is stronger than all men unwise, they can be got. . . . This I do clearly believe to be the backbone of all Future Society, as it has been of all Past; and that, without it, there is no Society possible in the world."

These are the sentiments of that powerful, rough, mainly accurate philosopher, as expressed in his 'Latter-Day Pamphlets,' about the middle of the nineteenth century. Carlyle, judging the works of men, would, I am sure, declare that the noblest work of all, in our time or in times to come, shall be adjudged that of the captain of industry, who, in his long life of struggle and of strife, leading armies of men to victories over material things and against obstacles set by ignorance, prejudice, opposing interests and envy and malice, finds employment for thousands, gives the people some essential of the people's life at continually reducing costs with continually rising wages, gathers his millions while giving to the nation hundreds of millions, and then, his struggles and strifes at an end, gives his remaining years to distribution of his wealth in the founding of libraries and to the support of the

higher education that he himself may lack. Greater than generals leading armies in battle, nobler than the founder of a family based upon wealth, grander than peer or even less self-abnegating royalty, his example is more inspiring than that of any so-called successful man, in any vocation, in any profession, in any station in life, *if* the exemplar lacks this splendid impulse to production of higher results in expenditure of wealth than in its accumulation. Name and fame and dignity and station all find eclipse in the greater name and fame and dignity and station of him who thus practically illustrates the workings of the soul of Abou ben Adhem. At the last, indeed, that man shall have all these and more; he shall add to them all that better reward, conviction of having earned the approval of conscience and of all good men, of all honest citizens and every patriot, of all men whose esteem is worth having in this world, and the pronouncement in the next: 'Well done, thou good and faithful servant!'

And what more splendid example, eliciting the finest ambitions of the young men coming after him, can there be than that of a man conquering success by overcoming every obstacle that fate can place in the way of the earnest man, gaining all the rewards of this world, and then —giving all back to the world in ways promoting its highest welfare!

I doubt if there can be one; yet I think I can see a modest rival. Not all men can become generals, colonels, captains in the army of industry; but a small fraction can even secure the sergeantcies. Many a man, starting out with high hopes and splendid promise, confident, brave and efficient, loses his hold upon the essentials of success and must settle back into a life comparatively unfruitful, if not absolutely unsuccessful as judged by our usual standard. Yet such a man may be the grander character, the greater hero. His world may be restricted to his little sphere of minor duty or even to his home; but even there opportunities will come to him, and his character may ripen, his influence broaden, his work ennoble him and all those about him. It is the spirit of the man that makes success and makes all opportunities fruitful, whether leading an army or serving as private in the world of finance, of business of whatever sort, or within the walls of a humble home.

The spirit of the *Man with the Muck-rake,* happily, is not that which inspires the young man of to-day. He is too intelligent and his thoughts rise to too high a level to be misled by the impulses of the miser; for he who pursues wealth alone, and for itself alone, is simply a miser. However brilliant and however fortunate and whatever the altitude of his position in the world of business, struggling simply for fortune and mere wealth for its own sake means a mean and miserly life. He is the man with the muck-rake. However large his pile of glittering dirt, it rises simply as a memorial to his folly and his vulgar

aspirations; it has no more value, unused for noble purposes, than any other mineral, than the most common and the dirtiest of dirt.

Struggling for wealth for a great purpose glorifies the otherwise inglorious contest with all the lowest elements of greed and selfish ambitions and meanness in all its protean forms. Williamson, living a life of almost miserly frugality, seeking and saving and piling up wealth from early manhood to old age, living and dying in apparent penury that he might do a great work at the end, becomes a noble figure when seen by the reflected light of his philanthropy and the fine closing act of that long, inglorious life. The founding of the Williamson School for orphan boys where they can find homes and careful training and apprenticeship to useful trades, and later work with selected masters and employers, is a deed which renders immortal the man whose life seemed so unheroic. That act built for him a memorial that shall last as long as human respect and admiration for heroic deeds and love for self-sacrifice, self-immolation in a good cause, shall endure. He gave opportunity to humble and poverty-laden youth aspiring to educate themselves for their work.

Already we are seeing evidence of the change that is coming and of the value of careful training of the gymnastic and the educational improvement of the man through systematic and scientific instruction and drill. The leaders of even the world of business are educated men, as a rule. Morgan, the leader of finance to-day, is a college-man, a graduate of Göttingen; none of this class of men is likely to advocate the endeavor of a people to become a crowd of wealthy boors rather than a nation of gentlemen, scholars and wise men. The great financiers of the country are now usually college-men; the heads of railways are often of that class, even though they have begun at the foot of the ladder; all distinctively learned men are of that class; our greatest men in literature, science and art are practically all educated and cultivated men; the inventors of the telegraph and the telephone were both educated and, in fact, learned men; all the great men in medicine and surgery are college-men; all the great lawyers and every great jurist on the bench is of the same rating. We make our presidents of learned men and usually of college-men; the same is true of the members of their cabinets, of the judges on the Supreme Court bench, of the chiefs of bureau, and practically all men in highly responsible positions. Our foreign ministers and ambassadors where reflecting special credit upon their country, like Lowell and White and Hay and Choate, have been not only college-men but distinguished for their attainments in the highest fields of academic learning.

In engineering no man will in the coming generation have even an average chance of success professionally, without uniting to the essentials characteristic of a 'general of industry' in generations

just past the now hardly less essential requisites furnished him by systematic instruction in the sciences underlying his art and the applied sciences and the scientific methods fundamental to his profession. Now and then a man may get on and even possibly attain a high or leading rank; but it will be at enormous sacrifice of strength, energy and physical vigor; and when he reaches his goal, it will prove that he has gathered 'apples of Sodom' for a 'Barmecide Feast' and he will mourn, as have so many before him, the lack of that which makes a life of independence and of liberty in expenditure worth having. He will probably, as have so many before him, if his long life of self-seeking has not poisoned his character and killed all his sympathies, seek the next best thing and try to help other later youth of ambition and energy secure what he so greatly needs.

While it is largely true, as has been asserted by more than one such man, like the fox in the fable seeking to justify his amputated tail, that the prizes of our time and our country are now being often grasped by the uncultivated and unlearned man, the fact is mainly due to the circumstances that these men of to-day are mainly uneducated through the misfortune that they were born too soon and before higher education had come to be general and suitable to the conditions of modern life. In another generation this situation will be modified in the direction of giving these opportunities to educated men in vastly larger proportion. Meantime, every successful man, lacking education, learning and culture, recognizes to-day, either that he has also lacked wisdom if deliberately declining to secure an education when young, or that he has been extremely unfortunate if deprived of that privilege by force of circumstances. Not a man of them but envies his poorest acquaintance who possesses the essentials of content in a life outside the narrowing and engrossing pursuits of a business life. He lacks preparation for precisely what all his energies have been directed toward—making suitable provisions for a profitable and happy life on a higher plane.

Visiting the famous Homestead steel works, some years ago, the gentleman who was taking me through the mills pointed out a strong, good-looking and evidently masterful man standing on the top of a set of heavy roll-housings in the armor-plate mills and remarked, 'That man is paid more than your college president' and, indicating another who was directing work not far away and who evidently belonged to the same class, the most intelligent of mechanics, he said: 'That man is getting pay exceeding that of any one of your professors.' Both men were soiled and grimy, dressed in overalls and, as occasion arose, ready to take a hand in the work, and to the unaccustomed eye of the casual visitor they would seem to be day-workman; but one familiar with such scenes would instantly detect the bearing and manner of the born gen-

eral, prepared through natural force of character to command. They were men from the ranks, active, ambitious, good workmen, strong, proud, yet pleasant in their intercourse with all about them, and perfectly well prepared for their places by knowledge, experience and natural fitness.

Why were these skilled mechanics paid the salaries of college presidents and of college professors? The answer is simple: They could make themselves so useful and so necessary in the business that the proprietors could make money by employing them, large as was their compensation. Precisely the same principle operates when the presidents of great corporations receive tens of thousands of dollars as salary, or fifty thousand or a hundred thousand. The directors of such enterprises do not give away a hundred thousand dollars simply out of kindness; their enormous interests compel them to seek out the one fittest man in all the country, the man who is sought by perhaps many other great enterprises as a guide and director, to make those interests safe; identifying him, him they must have at his own price. Similarly, the great leaders in the industries take a few millions of the many which they earn for the people; it is quite fair.

The unlearned and uneducated man will always have his place in this world of ours; but yet he will not hereafter have such opportunities, however great his natural abilities, as he has had in the past. It is sometimes—not very often—said by 'successful' men of this class that the boy who grows up without learning, and who gives his boyhood's years to unskilled labor in shops and factories and mills, may hope for a larger success than he who is taught sound learning or given a 'liberal and practical' education. They speak without foresight or forethought. The world of the coming generations is to be a very different world from that of these last, even as the last generation lived in a very different world from that of their fathers. Education is permeating the whole body politic and rapidly becoming distributed to all ranks in life. For one poor man's son in college a generation ago there are many to-day, and for one hundred years ago there are now the many multiplied, and the man who would succeed, in whatever rank of business life, in whatever profession, must hereafter meet in competition men who, in addition to all the native talent which he possesses, and all the energy, vigor and ambition which he may display, will have a brain stored with knowledge and scientifically cultivated and trained, and thus far better equipped than formerly for successful struggles with the world and for seizing the opportunities and meeting the responsibilities of the highest positions for which all may strive.

This is, in fact, admitted, and it is often asserted by the most wise and able and successful of this very class, and Andrew Carnegie is

founding libraries, is promoting technical education and is organizing a great technical institution as the noblest contribution of which he can conceive for the benefit of those working men to whom he owes so much and indebtedness to whom he so freely acknowledges. His great pupil, Mr. Schwab, while encouraging the penniless boy to begin bravely at the bottom and to work hopefully toward the top, still more emphatically declares his respect for learning, and his high estimate of the desirability of more general education, by himself organizing a trade-school for Pittsburgh. A very large part of the work of founding schools and colleges and universities and every form of higher, as well as primary, education, outside the common-school system of the United States, has been already done, and is being performed more and more generally and liberally and generously by this very class of men. Rockefeller builds up Chicago University; Ezra Cornell, uneducated and once in poverty, nevertheless gives all his surplus, once secured, to found a university in which 'any man may find instruction in any study' and interests himself most of all in providing for the poor man's son; Hiram Sibley, owing his millions to the same sturdy, manly and vigorous spirit, fighting his way from the bottom to the top, finds his noblest pleasure in organizing a college in which the education of the young mechanic and engineer may be carried up into the realms of applied science and the highest departments of professional work.

Lawrence and Sheffield, Case and Rose and Rensselaer, and the numerous other great philanthropists who have founded schools and colleges, even the most thoroughly educated and most cultured of all amongst them, it must be remembered, had no such educational opportunities as are offered the young men and women of to-day. The coming generation is to be comparatively highly educated people, and the man who is to succeed in dealing with the new, the modern, man must, more than ever before, have something of that culture. Highest success will only come of education and culture combined with a thorough scientific, professional preparation for the most advanced positions in the industrial or professional organization. In the past generations few men were given, or could be given, even the academic education of the time; to-day, almost any man who has the wish and a real determination to succeed may secure a good education of the kind which he may most desire. In the last generation the competition for the high places and grand prizes, outside the then so-called learned professions, occurred between uneducated men, as a rule; in the generations now coming forward that competition will be between men who have not only the brain and the native talent, but also, and superadded to all that the older type of man possessed, that kind of systematic training which makes the intellectual as well as the physical gymnast, that scientific instruction which provides learning that finds its peculiar

use in the industrial departments of life, out of which come, directly or indirectly, all great fortunes.

This is already coming into view as the characteristic change of the time in the making of the personality of the notable man of the time. To-day the educated men are taking their place in the world and their chances of success are, and have long been, vastly greater, in most directions, than those of the uneducated. The proportion of educated men taking their places in history is already fifty times as great as of the uneducated; the next generation will see practically all great prizes in their hands. It is a splendid evidence of the progress of the world that he who chooses may enter the ranks of the educated, and he who will may make himself a man of culture.

As for opportunity to gain the prizes of common life, 'what more can the college-man ask than he now receives?' One man in a hundred to-day obtains a college diploma; these men supply one third the Members of Congress, one half and more of our presidents and vice-presidents, two thirds of our Supreme Court justices, seven eights of the chief justices. In all ranks, in all great places, the names of immortals are in the proportion of fifty to one, favoring the college-man. If, as asserted by some writers of late, as I however think mistakenly, the proportion of college men to population is falling off, then so much the greater will be the opportunities of the wise. If, as presumably is the fact, college-men are more and more pursuing professional studies, that means the elevation of the professions to a higher level and still larger opportunities for the college-man fitted to lead. To-day, the college-man has thirty times as large an opportunity to succeed in public life as the non-graduate, fifty times as large an opportunity to reach the cabinet, the vice-presidency or the president's chair, sixty or seventy times as large a probability of success in striving for the Supreme Court, eighty or ninety times as favorable chances of becoming Chief Justice.

In the great industries there are probably a still larger proportion of positions which, without the scientific learning and systematic training in applied sciences given by the engineering schools, the most ambitious of men and the most talented could not attain or attaining, could not hold. The coming century will see these opportunities more and more the prize of intellect suitably trained, of mind properly strengthened, of talent precisely outfitted for the task of their acquirement. The college-man will come more and more generally to take and to hold one hundred per cent. of the positions assigned the generals in the great army of industry. This is the more probable since, as is asserted by a foreign and unprejudiced observer, 'The engineering profession is to-day, upon the whole, the best educated in America.'

In all the later centuries until the nineteenth, the college-man

seeking to unite with learning and culture, with knowledge and wisdom of the sorts approved by the older academicians, that no less noble and still more helpful learning of the sciences and of the arts of industry, joining the academic with the scientific and the professional, has been at a disadvantage among other college-men. The end of this discrimination among learnings is now in sight, and one of the most striking signs of the times in this direction is the recent action of the Emperor of Germany and his government, and of the Emperor of Austria-Hungary and his officials in ranking the scientific and the professional schools beside the universities.

Many years ago, at the instance of your annalist, was initiated the degree of Doctor in Engineering; later, it has come to be the fact that at least one university has established entire equality between its colleges of arts and sciences, those of applied science and engineering and its professional schools, both in requirements for entrance and in those for graduation, as well as in value of its degrees in those departments of learning. Only recently, the Emperor of Germany has announced the same democracy of learning for his country and the Emperor of Austria-Hungary has followed suit, making the doctorates of engineering and of the applied sciences, and the institutions permitted to confer them, co-equal with the doctorates of philosophy and their conferring universities.

I have wondered whether the presence of our distinguished scholar and teacher, Ex-President White, at the court of Germany has not had some influence in this progress; but, however that may be, the American democracy of learning is now accepted in Europe and the complete emancipation of the universities from the old monastic influence will not be long deferred. The making of the head of the great German 'Polytechnicum' a '*Rector Magnificus*' has a great and a most encouraging significance for all nations.

The college-man is he, who, in the days which are now come, when practically every one who wills can secure learning if not wisdom, knowledge if not culture, sees opening before him the largest and most attractive opportunities. Whatever any other man may possess, he has that which permits him to aspire to companionship with, if not leadership of, the greatest and noblest in the land and of the time. Given similar physical vigor, equally strong aspirations, similarly clear and strong intellect, no less refined sense of justice, sympathy and manly brotherhood with men, it is the college-man alone who has the advantage of systematic training of faculties, of most efficient teaching, of scientific knowledge and of highest learning through communion with the greatest men and the loftiest minds of the present and of the past, and who may with greatest confidence undertake the leadership of men. It is the college-man who is best equipped for generalship

in the industrial army, for farthest exploration of unknown fields of science, and for loftiest rise in the philosophical world and, even with similar elementary experience and training, for greatest success in the lower, but none the less great, world of money-makers. The twentieth century man will be the college-man, in type, and it will be college-men, as a rule, who may be expected to go farthest and rise highest and to do the great deeds of the coming centuries, whether in finance, in the industries, in political life or in the highest realms of science and the loftiest worlds of morals and philanthropy.

Shame be to him if, with all his advantages, he permits another to wrest from him that leadership by greater desert, by more perfect fitness. Glory be to him if he do his duty and splendidly, as he may, accomplish his grand task!

The college-man is evidently ere long to take charge of our public offices and of the industries and professional departments, and college-men are to find their way into prominent positions as never before; but, fortunately, college-men come from all sorts and conditions of people, and it can never be said that this means the organization of a class to dominate other classes, much less the masses. The sons of poor men, as a rule, always have been, and probably always will be, able to secure these positions oftener than the sons of rich men; for they have the discipline in early life that the latter usually lack. The process of promotion of the college-man is to be one, as well, of constant redistribution of power among all classes, very much as common experience shows the wealth of the country to be as constantly in process of redistribution. The democracy of intellect and the democracy of influence will be insured by this process in the most desirable of all possible ways. The way is now opening to the college-man as never before, and especially the departments of applied science and the industries offer him opportunities beside which those of the college-man in the other professions are insignificant.

In another generation the proportion of men, educated and uneducated, who attain success will be vastly changed, and, happily, the number of men who have reached competence or wealth in their vocations and who must still sigh that they cannot give of their millions to gain the education which they lack will be, probably, comparatively small—for the ambitious poor boy will much more commonly than now find his way to his triumph by way of the college or the professional school. The number of wealthy men who will esteem it a privilege to help on the work of education and to take part in other great works will undoubtedly also steadily increase until, as we may perhaps hope, the redistribution of surplus wealth may become the pleasure and the recognized duty of all.

The college-man, leaving college, goes out into life, once more a

freshman and with the university of life for his next place of struggle, of aspiration and of achievement. He enters upon a new training by different methods and through radically different experiences. He is trained indeed but by no sympathetic and systematic teachers. He must find his own way to knowledge, and to wisdom which is greater than knowledge, and must struggle onward and upward with not only little assistance, but even with almost every man's hand against him and driven, at times, to raise his hand against every man except the select few whose interests or whose convictions coincide with his own and are opposed by all the world beside. But this is not difficult for the man who knows himself in the right. In all men, it is obvious to the close observer, there exists a fighting instinct which has its use in life and the joy of contest makes easier the struggle for the intended goal.

Honesty, ability, capacity and power, supplemented by precisely the right sort of learning and made available through systematic training, in every case prove winning quantities. The complete development of the man to a maximum of usefulness in the vocation and the life to which he is by nature best fitted, means progress and ultimate success —*provided* he can keep himself in training. An essential element of the art of success is that of living long enough and in a state of high working efficiency. The fact that this is so generally ignored makes the opportunity of the man who never forgets it all the larger.

It is also the fact that it must be admitted that the incapacity, the lack of integrity, the indifference to duty and the general inefficiency of the average man is one of the elements of the success of the man who does finally succeed. But, sad as is the fact, it may fairly be accepted by the man who is at once gentleman and scholar and expert, as contributing to his opportunity.

And now, at this period of blossoms and nature's most beautiful season of promise and of hope, our young men and our young women are going out from the colleges to meet their opportunities. In these early days of the twentieth century, the college-man is the man of the century as never before, and the college-woman is, as never before, his most efficient helpmeet. All paths open to them and all fields are theirs for cultivation and 'all sorts and conditions of men' look to them for leadership and guidance. Theirs it is to prepare for leadership of every industrial army, for conquest of every unknown kingdom in nature's as yet unexplored realms, for discovery of uncounted secrets of the mysterious workings of physical law, of sources of energy and of new methods of utilizing all forces and all substances. These are they who shall become generals in the industrial armies, expounders of law, presidents, capitalists, benefactors of humanity.

For every one, if he will but seek it, there lies ahead a career as full of accomplishment, of honor, of usefulness to the world as his best

aspirations can reach, if he will but use his talents, his physical powers and his moral sense to the full extent of his capacity. His it is to lead in invention, in every art, in manufactures, in commerce, in philosophy, in morals, in accomplishment of the destiny of the century. Not all will lead, but all may follow where they cannot lead, and every one may do a good best and reap a reward proportional to the earnestness, the energy, the ambition and the discretion which he may display in usefully employing the learning and wisdom and the *savoir faire* which he may have acquired. Not all may become generals, but each may become colonel, major, captain or lieutenant, as his capacity and ability may give opportunity; each will gain quite enough to give satisfaction and ultimate profit. Patience and contentment were the ideals of the earlier times; but to-day the word is ambition and determination to make the most and the best of opportunity; content and patience are now means to an end and the end is accomplishment. To be content with what is gained but ambitious to secure new prizes, to be patient in struggling against obstacles while none the less determined to overcome them, are principles of life for twentieth century men and women.

Success in business and in professional life is simply the means to an end and that end is the power of helping forward the brotherhood of man. A competence is sought by each and all; but it is competence to secure, when the struggle is past, opportunity for greater deeds in the promotion of all good works, as well as in the enjoyment of all the wonderful things that the century shall offer to the cultured, the learned, the wise man. Wealth has its attractions for all honest men; but it is desired by the wise man only that he may emulate the great men who have already shown what good may be accomplished by its powerful enginery.

The twentieth century man is the college-man; and the college-man who is hereafter to lead and who will be remembered as a leader is he who uses his splendid equipment for the advantage of his fellows.

The 'self-made man' commands honor and compels our admiration; but the self-made man is usually a very incomplete piece of work and his kind will less and less hereafter succeed in competition among more perfect men in the life of the coming days. Only the man who has had a systematic education and training can hope to successfully compete with the world's leaders, educated, able, learned and strong as they must be, and possessing, as they must, also, quite as much natural power and constitutional vigor as he. The twentieth century man, the college-bred man, doing his best will do a better best than can the other man without the now essential knowledge and culture.

THEOLOGY VERSUS THRIFT IN THE BLACK BELT.

BY CHARLES BARTLETT DYKE,
HONOLULU.

THE negro's real menace to the South lies in the paucity of his earthly wants. His few demands upon the world can be met with little exertion, and the outgrowth of his indolence is vice and crime. Generations of slavery have crushed out the spirit of accumulation. The 'collecting instinct' so prominent in the early life of the white child, is almost lacking in the average negro child of the South. Poverty, even though it may entail dishonesty, is too often accepted as a dispensation of Providence, to be compensated for later by the glories of Heaven.

A recent study of twelve hundred negro children brings out strongly their limited ideas of what constitutes wealth, their lack of thrift, and the sanction placed upon poverty by their religious teachers.* These children returned written answers to the following questions:

Would you like to be rich? Why? How much money of your own did you have last week? What did you do with it?

One half of the replies came from the cities of Wilmington (Del.), Baltimore, Washington, Norfolk, Newport News and Hampton. The other half came from the most enlightened rural districts of Virginia, Georgia, North Carolina and Alabama.

To all these children, from city and country alike, wealth means only the satisfaction of the simplest and most legitimate wants. To wear shoes and an overcoat when it is cold, and to have a hot fire in the winter, to have enough money to pay the landlord and the grocer, to own a horse or a cow or a mule, to assist the mother, so that she will not have to go out washing every day—this is their idea of riches. A boy of twelve wants wealth "So I could be more comfortable and have a better home than I have at this time. If I was the writ kind of a man I would spen it for food or wood or coal for to burn."

Girls of thirteen write, as reasons for wanting to be rich: "When you want anything you get it, and you don't hafter sit down and wish for it because you don't get it when you wish." "Poor people cannot have anything they want because they have to pay store bills, and the landlord is running to the house every Saturday night for rent."

* The writer wishes to thank for valuable material Miss Kruse, of Wilmington, Del.; Miss Grooms, of Baltimore; Mr. Cardoza, of Washington, and the members of Mrs. Dyke's Hampton Child Study Circle.

Several children wish for wealth 'because so many white people are rich' and a boy of thirteen explains, 'If I were rich the white man would not cry my name down but would be my friend.'

It is a regrettable fact that one fifth of the children who desire wealth, expect to 'live bedout working,' as a nine year old boy puts it. Aladdin's lamp is sadly missing from the lives of these twelve hundred children. Their most extravagant desires are as limited in scope as the children voicing them are limited in number. Ten children would travel if wealthy, seven would run a store, two would be conductors on street-cars, five would own pianos, four bicycles, one a 'five-dollar doll' and one a horseless carriage.

But pathetically limited as is their idea of wealth and the wants which it would supply, half of the older children from the rural districts reply with a decided negative to the question 'Would you like to be rich?' Their religion has forced them to choose between comfort in this world and bliss in the next. A girl of sixteen expresses the prevailing sentiment in her answer. "No, I would not like to be rich. Because the Bible say it is just as impossible for a rich man to get to heaven as it is for a camel to get through a cambrac needle eye." *

As is shown by the following table, the hostility toward riches is an increasing factor in the lives of both city and country children.

THE ATTITUDE OF NEGRO CHILDREN TOWARD WEALTH.

Ages.	6 to 10.		11 to 13.		14 to 20.		All ages.	
	City.	Country.	City.	Country.	City.	Country.	City.	Country.
Percentage desiring wealth.	93	82	90	70	83	50	91	65
Percentage desiring poverty.	7	18	10	30	17	50	9	35

While fewer than one fifth of the older children living in cities repudiate wealth, one half of the country children from fourteen to twenty years of age distinctly declare their preference for poverty.

The children of the city poor usually see the ordinary comforts of life in evidence among their more fortunate neighbors and often their ambition is aroused to acquire equally desirable property. On the other hand, in the rural districts the standard of living varies less widely, and there is less evidence of prosperity to stimulate the desire for wealth. However, the disproportionate number of country children who exalt poverty does not depend upon the merely passive effect of neighborhood conditions. Their papers bear proof of positive teaching that the accumulation of property is opposed to religion. Almost all who repudiate wealth do so on religious grounds. Between the

* The common 'reading' of Mark 10, 25, by illiterate preachers.

civitas diaboli of the wealthy and the *civitas Dei* of the poor a sharp distinction is drawn. The wealthy are declared to be sickly, discontented and unhappy, spending their nights sleeplessly guarding their treasure. They are wicked and cruel, and 'get their wealth by stealing from the poor.' A girl of sixteen sums up the general impression in her statement that 'A rich person never feels happy, they is always sad and unhappy.' 'Them that is not rich is happy Always.' The attitude of the great majority is that 'God don't leck rich folks.'

The following replies are typical of this sentiment:

Girl, 11. Rich people is always sickly and poor people has good health.

Girl, 12. No, because I would not be good to my little brother.

Boy, 15. No, I wouldn't do justice to every one.

Girl, 15. No, I would not like to be rich because a rich person will not enter the Kingdom of Heaven. I would rather be poor and be kind and gentle in my manner.

Girl, 16. I would not like to be rich for—

> I care not for riches,
> Neither silver nor gold,
> I would make sure of heaven,
> I would enter the fold.

Boy, 17. No, I would forget the Lord and put my whole heart and mind in my riches.

Boy, 20. I don't care to ever be rich. If I were rich it might come to me to turn to the things of the world, and not on heavenly affairs.

Bearing in mind that wealth in the Black Belt means merely a decent standard of living, we must regard the religious ban placed upon its accumulation as a positive encouragement of unthrift.

The children's record of their expenditures for one week bears out this conclusion. The average amount possessed by each of the twelve hundred children, was twenty-five cents, earned by the majority in such ways as gathering corn and hay, sailing a boat, selling oysters, papers and scrap iron, running errands and carrying packages, picking over cinders and 'writing a letter for a lady.' It is difficult for the children to account for the use of their money.

'I spen it honest,' 'I spent it for things,' 'I spent it for my use' indicate, not reluctance to divulge private affairs, but the fatal facility with which their money escapes them. Burial society dues,* school material, car rides and clothing, including such elegancies as 'a backing comb' and 'two yards of second moning' are among the expenditures mentioned. The largest item for expenditure is for dainties—candy,

* The majority of negro children in the South belong to burial societies, which, in consideration of small weekly payments, agree to furnish them a funeral with certain desirable accessories, a hearse with plumes, a specified number of carriages, etc.

peanuts, pickles, cheese and cakes—to the average amount of about four cents per child. The same average amount is temporarily kept by each child. As it is often stated, 'When I get some more to put with it I will get something I want.' The idea of putting money away for some definite future use is rarely found.

Booker Washington's 'great quadrivium' for his people consists in the arts of acquiring 'property, economy, education and Christian character.' The success of Hampton and Tuskegee lies in the habits which they form of thrift and industry, and in the new wants which their students can supply by the exercise of their trades. No graduate from either school will be contented without a home of his own, sufficiently roomy to ensure decent privacy, supplied with clean and comfortable furniture, with pictures and with books, and with a plot of land large enough for vegetables and flowers. But in the Black Belt this constitutes the wealth which is condemned by the theology of an uneducated ministry.

This theology is undoubtedly an outgrowth of slavery. It was most desirable to suppress in slaves any ambition to own property. But the great obstacle to useful citizenship to-day is this very lack of ambition. For sloth and extravagance are justified by the belief that God has placed a ban upon the fruits of industry and foresight.*

It is a significant fact that only three children find any religious sanction for accumulating property. A girl of thirteen declares that: 'The Lord put something on this earth for everyone,' and another justifies herself by the statement: 'My Father in Heaven is rich.' An Alabama boy of seventeen writes, 'I would like to be rich because I could serve God better. I wouldn't have to plow and get angry with the mules.' A girl of eighteen sends a beautiful specimen of casuistry. "I would like to be rich, then I would be able to live above wants. Though the Bible says it is impossible for a rich man to enter the Kingdom of Heaven. But I would trust God. Because there is nothing impossible with God."

The different religious teaching of city children certainly accounts largely for their different attitude towards wealth. Among the negro clergymen of the cities represented are men distinguished for broad training, for careful investigation of social conditions and for rare personal devotion. Realizing that the progress of their race depends largely upon its industrial development they constantly exalt thrift and a good standard of living in their teachings. There is no present danger that the growth of avarice will destroy the negro's religious sentiment. Sufficient to keep this alive for many generations is his

* A Georgia deacon is reported who was deposed from his official position in the church because he had acquired 10 acres of land and was therefore considered unable to 'keep his mind on heavenly affairs.'

inextinguishable brotherly love. The generosity of the Southern negro both in spirit and in deed is his most lovable trait. There is always room in the poorest cabin for the child of misfortune, and that family is a rare one which does not contain one or more adopted children—the orphaned or abandoned offspring of the unfortunate. In the hungry barren lives of these poor negro children the first thought of wealth is what it would do for father and mother or 'for my people.' Sixty per cent. of the children between fourteen and twenty, who wish to be wealthy, are actuated by thoughts of others.

The following papers are typical of this spirit:

Boy, 14. I would like to be rich so when any poor man come to my door, I would give him something.

Boy, 14. I would like very well to be rich because my father and mother would not hafter work. All they would do to eat and sleep.

Girl, 14. Yes, so I could take care of poor and motherless children.

Boy, 18. My home would be better and I would pay some of those children's tuitions who have to leave school, and I would try to make it possible for them to earn more money.

Scattered throughout the South are scores of educated negro men and women whose lives of noble devotion to their people are testifying to this spirit of brotherly love. Of inestimable value in their work would be the aid of pastors, industrially trained, who by teaching and example sanctioned 'property, economy, education and Christian character.' The inherent generosity of the negro character might easily be made the moving force in material accumulation, and so clothe it with righteousness. But perhaps the greatest foes of rational progress are the untrained preachers who destroy initiative and check energy.

This study certainly emphasizes the correctness of the statement recently made by the Hon. William T. Harris:* "The crying need at the present day is for an educated pulpit, among the colored people of the South. The majority of these ministers are illiterate and ignorant, and their congregations are filled with superstition, some acquired and some hereditary, as a characteristic of the African race."

* Quoted in Washington 'Post,' May 10, 1900, from Dr. Harris's address at the graduation exercises of the Training School for Nurses at the Freedmen's Hospital.

THE DESCENT OF MAN.

BY PROFESSOR LINDLEY M. KEASBEY,
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GENERAL evolutionary evidence led anthropologists some time ago to postulate a pliocene precursor of man, but their surmise has only recently been substantiated by particular proof. The search for the so-called missing link was at first confined to the temperate zone. Many discoveries were made, but, as the skulls and implements unearthed were all taken from pleistocene deposits, there was nothing to indicate the existence of man on earth before quaternary times. It was not, indeed, until investigations were transferred to the tropics that earlier vestiges of human life were revealed. In the year 1894 Dr. Eugene Dubois discovered the upper portion of a skull and some skeletal parts of a distinctly human creature buried in the pliocene beds of East Java. These remains have since been subjected to the strictest scientific scrutiny and pronounced genuine. Taking the geological location of the discovery into account, there can be no further doubt, therefore, that in this tropical region the human species was already differentiated from the apes in tertiary times.

Judging from the size and form of the skull, and from such portions of the skeleton as remain, the variation of the human prototype, or to give him his scientific name, *Pithecanthropus erectus,* was evidently along both psychic and physical lines; the former showing a difference of degree, the latter exhibiting a distinction in kind.

There are two anatomical tests of intellectual superiority: cranial capacity and the convolutions of the brain, both of which can be applied in the present instance. It is a well-known fact that the frontal bone, which forms the vault of the anterior part of the cranium of young men and apes, is divided by a suture. So long as this line of growth remains open, the fore part of the cranium can expand; but if the anterior sutures of the skull consolidate early in life, the cranium cannot increase in capacity beyond the size reached in early infancy. In consequence of the early closure of these sutures in the anthropoid apes, the cranial capacity of these creatures is restricted, and the fore part of their brain rarely increases beyond the size attained at the end of the first year of life. With man, however, these sutures do not consolidate until a much later period, and, as the anterior lobes of the brain continue to develop, human cranial capacity increases accordingly. As a result, the average human being possesses four times as

much brain surface as the anthropoid ape. Applying this test to the human prototype, we find that Pithecanthropus occupies an intermediate position between the higher apes and modern man. That is to say: if we set specimen anthropoid skulls in an ascending series according to cranial capacity, we shall discover that between the higher apes and Pithecanthropus there is a considerable gap; Pithecanthropus is followed shortly in the scale by the Neanderthal group of men, whose skulls were found in the quaternary deposits of Europe; these in turn are succeeded by the crania of the lowest living savages; and from this point the series runs on without interruption through the various races of man to the highest existing types. Thus on the human side there is practically no break in the gradual development of cranial capacity from tertiary to quaternary, and upwards through prehistoric to historic man. The only interval that occurs is on the animal side, between the lowest type of man and the highest type of ape; from which we may infer that the pliocene precursor stood considerably above his simian relatives in intellectual capacity, though the difference was merely one of degree.

The same result is reached by a comparative study of the convolutions of the brain. It has been demonstrated that the gyri of the brains of man and the anthropoid apes are similar, with the exception of the convolutions which enter into the formation of the frontal lobes. The superior and middle gyri of these lobes are much shorter in the brains of anthropoid apes than they are in the brains of man, and in the brains of anthropoid apes the inferior frontal gyri only exist in rudimentary form. These anterior lobes of the brain, or more exactly their cortical nerve elements, to a large extent control the higher intellectual faculties. The condition of these frontal convolutions is, therefore, like cranial capacity, an index of mental endowment. Applying this test to the human prototype, we find that with respect to his cerebral convolutions, Pithecanthropus stood considerably above the other anthropoids, and within the line of development leading to the higher human types. This is proved by the impressions on the interior of the Java skull, which show that the superficies of the convolution of the prototype's brain was double that of the largest brain of any anthropoid ape, and somewhat less than half that of the brain of modern man. The convolutions themselves are also well marked and distinctly human in form. Thus whether we judge from cranial capacity or from cerebral convolutions, it is evident that the pliocene precursor was psychically differentiated from the apes and endowed with the intellectual attributes of man.

Along physical lines the modification is even more marked. From the shape of the femur (discovered in close proximity to the skull), it is evident that Pithecanthropus stood erect and walked upright on the

earth. If not already become, the prototype was, therefore, certainly in the course of becoming, a true biped, using his legs alone for locomotion and developing perfectly plantigrade feet. Freed from further service for locomotive purposes, his arms had, no doubt, become relatively short and his hands exclusively prehensile. In all these respects the reconstructed skeleton of Pithecanthropus shows a striking divergence from the characteristic anthropoid type. The apes as a group are stoop-shouldered tree-dwellers, with hands and feet primarily adapted to swinging and climbing. Even the few varieties that dwell habitually upon the ground, of which the baboon is the best example, have not lost their inherited ability to climb, while in walking these creatures have reverted to the quadruped habit. Some of the arboreal apes also come occasionally to the ground; but when they walk, these animals adopt a crouching attitude and use their arms as aids to locomotion. The gibbon is, in fact, the sole ape that walks erect, and this is only possible in his case by reason of the extraordinary length of his arms. When unconcerned this creature walks with his long arms held aloft like balancing poles and hands outstretched to grasp any overhanging support, but when frightened the gibbon likewise drops his arms to the ground and swings along between them as if on crutches. Taking structural characteristics into account, it is, therefore, possible to draw a sharp distinction between the short-legged, long-armed, stoop-shouldered, arboreal ape, and the long-legged, short-armed, erect, surface-dwelling ancestor of man.

Specific variation in the biological sense is the accomplishment of that which variability permits, environment requires, and selection directs. No stock or lineage breeds perfectly true; the line of every descent is marked by certain modifications. The general tendency of such modification is toward the preservation of the more useful and the extinction of the less useful or useless characters. Survival is thus the result of the selection of such variations as adapt the organism to its environment, the more plastic the organism the greater the possibility of variation; the more favorable the environment the higher the type of animal evolved. Attributing variability, then, to the anthropoid stock, from the fact of man's survival, we may presume that the modifications characteristic of the human species were favorable in this sense, that they adapted the pliocene precursor to his mundane environment. Judging from the further fact that the tree-dwelling apes have long since reached the stationary stage, while land-dwelling man has steadily continued to advance, we are also justified in considering the terrestrial habitat more advantageous than the arboreal abode. The descent of man appears, accordingly, to be marked by progress along the line of heredity and improvement in the way of environment, selection in this instance giving rise to a distinctly superior species.

Passing over to particulars, it is pertinent to enquire wherein this specific superiority consisted. In what respect was the erect ground-walking human prototype better fitted for advancement than his stoop-shouldered arboreal ancestors? Favorable structural and environmental variations are, generally speaking, along two lines: those that enable animals to escape more easily from their enemies, and those that place them in a better position to acquire sustenance for themselves. It is impossible to conceive that the pliocene precursor gained any advantage over his ape-like ancestors in the former direction by adopting an upright attitude and abandoning his arboreal abode; for in so doing he lost his earlier and easier means of escape through the trees, without acquiring by way of compensation any corresponding facility for taking flight on foot. The only alternative is, therefore, to suppose that the superiority of the human species was in connection with the food-quest. As far as quantity was concerned there was nothing, however, to be gained by coming down from the boughs, for the trees of the tertiary forest afforded a supply of nuts and fruits far in excess of the demand. The advantage must, therefore, have been qualitative, that is to say, in the way of a wider food-choice. As an erect, surface-dwelling creature man was evidently able to secure a greater variety of subsistence than his ape-like ancestors obtained from the trees. Being arboreal their food was confined to nuts and fruits, while by becoming terrestrial he was in a position to add roots and berries, and, in the course of time, also fish and flesh to his fare. Human progress appears, accordingly, to have been away from a strictly frugivorous in the direction of an omnivorous diet. A similar tendency is observable among the other anthropoids. The arboreal apes, for instance, are naturally frugivorous, but when taken from the trees and bred in captivity they readily become omnivorous. The semi-terrestrial types exhibit the same proclivities in their wild state. The gorilla, for example, usually lives on fruits, but also eats birds and their eggs, small mammals, reptiles and the like, and has even been observed to devour large animals when found dead. What is only an incipient tendency among the apes probably became an habitual practice with the ancestor of man. The superiority of the human being may thus be said to have consisted in the acquisition of qualities and the occupation of an environment which enabled him to widen the range of his food-choice.

It is evident enough that the variation of environment was favorable in this respect, for the terrestrial habitat certainly offered boundless opportunities for the development of an omnivorous taste; but it is not so easy to see how the characters we have described as human rendered these opportunities available. Berries and roots were plenty in the woods, the streams were alive with fish, and the tertiary forest

abounded in game of all sorts; but the superficial food-ground was already preempted by other animals, which were not likely to allow man to encroach upon their subsistence without a struggle. Adaptation to the new surroundings must consequently have been effected at the expense of a conflict with the former lords of the forest. But the human prototype does not appear to have become fitted for such a contest either through heredity or environment. From his ape-like ancestors the pliocene precursor merely inherited a large cranial capacity and the ordinary anthropoid characters; while in adapting him to the terrestrial habitat, selection simply set him upright on his feet and accorded him the free use of his arms and hands. Leaving aside his inherited endowment for the moment, the structural modifications that occurred during the period of specific differentiation seem at first sight to have set man at a positive disadvantage over against the frugivorous apes, on the one hand, from whom he descended, and the land-dwelling carnivora, on the other, with whom he had henceforth to contend. The food of frugivorous creatures remains fixed in its place and only requires to be plucked. These animals have, therefore, no need of powerful prehensile organs in attack, while for defense they usually rely upon their locomotive organs in flight. The prey of carnivorous creatures has, on the contrary, to be caught and killed, and on this account these animals are supplied with vigorous attacking organs, which in times of necessity may readily be employed for defense. The apparent anomaly in man's case is that in becoming terrestrial, he lost his former facility for climbing and making his escape through the trees, without by way of compensation acquiring sufficient strength or agility to cope with the land-dwelling carnivora. Cut off from escape above and surrounded with animal enemies below, physically unfitted to lie in wait and spring, having neither claws nor talons wherewith to grasp and hold, and not being fleet enough either to take flight or to follow fast on foot, how then was it possible for man to gain his acknowledged ascendancy over the beasts?

As a group the anthropoidea are structurally adapted to two sets of physical exercises: swinging and climbing, and striking and throwing. In a more restricted sense, however, the two practices are incompatible, for skill in one direction can only be acquired at the expense of proficiency in the other. For the former exercises, moreover, instinct alone is sufficient; while for the latter a certain amount of ingenuity is required. Being arboreal, swinging and climbing are essential to the frugivorous apes, both for food-getting and for flight, and on this account their instincts are set and their organs especially adapted to this purpose. Those that come occasionally to the ground in search of other aliment are, however, also able after a fashion to strike and throw. Both the gorilla and the chimpanzee, for example, are in-

genious enough to swing sticks, and the orang will break off branches and fling them at his tormentors or hurl the thick husks of the durian fruit. Nevertheless, striking and throwing are exceptional even with the semi-terrestrial apes, or at most only occasional exercises with such as have sometimes to defend themselves upon the ground. But for man the conditions were reversed. After the human prototype had parted company with his arboreal fellows to become a land-dwelling creature, swinging and climbing were no longer essential to his success. Henceforth he had to win a place for himself on the ground, and lacking natural means of attack and defense, in the course of his contest with the carnivora, he was compelled to exercise ingenuity in the choice of artificial implements and develop his incipient capacity to strike and throw. It is not so strange, therefore, as it at first sight appeared, that in adapting the human prototype to his earthly environment selection should have simply set him upright on his feet and accorded him the free use of his arms and hands; for, with his inherited mental endowment, these slight structural modifications were just such as were necessary to make him a weapon-wielding animal and so set him above his enemies.

But besides becoming psychically and physically fitted for striking and throwing, man's faculties had also to be trained before he could acquire proficiency in the art of weapon-wielding. To deal a straight blow with a club, or hit a distant mark with a missile, it is necessary to take accurate aim; and this involves the development of a good eye. Heredity favored the human prototype in this respect, for his ape-like ancestors had for centuries been accustomed to rely upon their sense of sight in their search for subsistence. In developing his incipient capacity to strike and throw, the pliocene precursor had, therefore, simply to turn his inherited acquisitive sense to the additional service of distance-determining and range-finding. Long practice and hard training must, nevertheless, have been necessary before primeval man acquired the knack of aiming accurately. The semi-terrestrial apes, whose instincts are still set and whose organs are primarily adapted to swinging and climbing, have never acquired any special facility in this direction. With the exception, indeed, of the land-dwelling, tree-climbing baboon, who is apparently able to hurl branches and hard clods with considerable dexterity, they all exhibit a ludicrous lack of skill in striking and throwing. On the other hand, by dint of observation and imitation, the small boy of our day soon learns to take accurate aim, and savages without exception show surprising skill in this direction. Considering the necessity of the case, and judging from the fact of human survival, it is extremely probable, therefore, that in the course of his contest with the carnivora the prototype acquired the knack of aiming accurately and eventually became an adept in the art of weapon-wielding.

The keen eye that the human prototype inherited from his ape-like precursors was also useful to him in other ways, for food-getting, path-finding and perceptive purposes in general. In some respects, indeed, sight may be regarded as the most serviceable of all the senses. Touch and taste, upon which the lower orders of life rely, require actual contact with the objects to be distinguished, and, consequently, only afford a concept of the immediate environment. Hearing and smell predominate among the vertebrates, have a broader range and are especially useful in this, that they allow the mind to distinguish particular sounds and odors from surrounding conditions, and so afford a perception of the local environment. The sense of sight offers still further advantages in that it conveys a concept of the special as well as of the universal environment and allows the mind not only to distinguish particular objects, but also to compare them with each other and so form a general conception of the outer world. Sight has this disadvantage, however: it only gives instantaneous information from one quarter, and necessitates a turning of the head or body to take in surrounding conditions, because light travels only along straight lines; whereas hearing and smell accord instantaneous information from all quarters, because sounds and odors disseminate in every direction from the center of disturbance. Thus though primeval man might well enough have relied upon his sense of sight exclusively for acquisitive purposes, defense demanded that he develop a sentinel sense besides. Heredity also determined this choice. Like the other anthropoids, man continued to rely upon his hearing to warn him of danger approaching from behind. Thus beside becoming adapted to walking and weapon-wielding, we may imagine the human prototype developing during the process of differentiation which fitted him for his mundane career, the keen eye and acute ear that had been handed down to him through heredity from his ape-like ancestors.

Working upon the biological principle of variability and following the interaction between heredity and environment, by a process of reconstruction we have been able to form a tolerably complete conception of the original condition of man. He was evidently a land-dwelling, omnivorous, weapon-wielding animal. For this manner of life he was psychically and physically fitted during the process of specific differentiation. From his ape-like ancestors he inherited his prehensile hand, his keen eye and his acute ear; in adapting him to the earthly environment selection increased his cranial capacity, developed the convolutions of his brain, set him upright on his feet and accorded him the free use of his arms for acquisitive purposes. Thus endowed, primeval man was evidently enabled to cope successfully with the carnivora, and eventually make himself master of the forest.

Taking the geological location of the remains of Pithecanthropus

into consideration, we concluded that the differentiation of the human species took place during tertiary times. Reasoning in like manner from the geographical situation of the discovery, we may suppose Indo-Malaysia to have been the cradle-land of mankind. The assumption is further substantiated by the fact that this tropical region is still the home of many of the higher apes, and was probably the point of departure for the dispersion of the other anthropoids. If we turn, now, to the evidences of quaternary culture we shall find a multitude of human relics buried in the pleistocene or post-pleistocene deposits of every continent of the globe. The widespread diffusion of these remains proves beyond peradventure the existence of man in every quarter of the earth at the beginning of the prehistoric epoch. Obviously, then, the descendants of the pliocene precursor must have wandered far and wide from the original abode during the long geological era that elapsed between the pliocene and post-pleistocene periods. It is incumbent on us, therefore, to determine how this migratory movement was effected. Close upon the problem of the differentiation of the human species comes, in other words, that of the dispersion of mankind over the face of the earth.

Subjectively speaking, there were evidently no difficulties in the way. The human prototype was, as we know, structurally fitted to walk, and his omnivorous manner of life must in itself have led him further and further forth in search of subsistence. In so far as physical capacity and psychic motive are concerned we may, therefore, think of the pliocene precursor as an ambulatory, omnivagant animal. It is only when objective conditions are taken into account that obstacles appear to arise. Granting primeval man's ability and desire to wander, how are we to imagine he endured the vicissitudes of climate that met him on the march? and how are we to suppose he crossed the seas that separate the several continents? Before the great antiquity of the human race was assured, it was necessary to assume an almost miraculous power of adaptation on man's part, and furthermore to endow him, somewhat inconsequently, with an innate knowledge of navigation; but now that science has succeeded in tracing man's ancestry back to tertiary times, we may more logically accept the explanation that geology affords. Instead of proceeding upon the presumption that the climate and configuration of the earth was then as it is now, we must reckon with the geological changes that have since occurred and work out our conclusions accordingly. In so doing we shall find that during these early ages of his existence on earth, environmental influences opposed no insuperable barriers before the dispersive propensities of man.

If, as we have supposed, the prototype was differentiated from the apes in Indo-Malaysia during the pliocene period, and arrived in re-

mote regions of the earth before the prehistoric epoch, the dispersion of the human race must have been coincident with the ice age. It is with the climatic and topographic condition of the glacial period, therefore, that we have to do in determining the original routes of migration. According to the astronomical explanation of glacial phenomena, which best accords with the geological facts as far as they are known, the Northern and Southern Hemispheres were alternately subjected to frigid conditions. Owing, however, to the disposition of the land-masses of the globe, glacial influences were more widespread in the north than in the south. When the glaciers proceeded from the arctic regions, the climate of the northern continents grew cold, the thermal equator moved somewhat south of the geographical equator and the southern peninsulas became predominately tropical. When, on the other hand, the ice advanced from the antarctic regions, the highlands of the southern peninsulas were glaciated, and, as the thermal equator moved north of the geographical equator, the northern continents enjoyed an equable climate, ranging from tropical to temperate conditions and devoid of great seasonal variations. Several such glacial cycles appear to have elapsed during quaternary times. After the third advance of the ice from the north, however, the glaciation of the hemispheres became less severe and the genial conditions more permanent, until, towards the end of the great ice-age, the glaciers were confined to the arctic and antarctic regions, and the globe became divided as at present into temperature zones.

As the ice advanced for the first time from the arctic regions, the temperature of the Northern Hemisphere became gradually colder, until during the early part of the pleistocene period, continental glaciers spread down over central Europe and North America. The increasing frigidity of the Eurasian continent at this time was doubtless sufficient to deter dispersion from the Indo-Malaysian cradle-land towards the north. Mountain ranges also hindered progress in this direction, for the Himalayas must have acted as a barrier towards Asia and tended to deflect the lines of migration east and west along the central latitudes. Immediately preceding and during the first glacial epoch, therefore, climatic and topographic influences combined to confine the original course of dispersion within the Indo-Mediterranean-Malaysian belt and the lower peninsulas of the Old World. This southern portion of the Eastern Hemisphere, it should be noticed, is separated from the northern continental area by a broken mountain range, running from the Himalayas to the Pyrenees. These mural masses protected the low-lying lands along the southerly slopes of the mountains from the increasing cold of the glaciated north, so that in spite of the fact that the thermal equator ran somewhat south of the geographical equator at this time, tolerable climatic conditions prevailed everywhere below

the Himalayan line. In these early days, moreover, the penisula portion of the Old World constituted a practically continuous land-mass. Toward the west India was connected with Africa, and Africa was joined to Europe by two or more isthmuses. In the opposite direction, the Malaysian peninsula was extended toward Australia through what are now the separate islands of Sumatra, Borneo and Java; Australia was likewise connected with New Guinea, and the immense island continent thus constituted was to all intents and purposes coterminous with the southeasterly extensions of Malaysia. It must have been possible, therefore, at this time for primeval man to proceed from the Indo-Malaysian abode along the central latitudes, to the Atlantic on the west, and far out across the Pacific on the east, without having to cross the open seas.

During the course of the pleistocene period the ice disappeared from the north and glaciation set in from the south, the glaciers in this instance proceeding from the antarctic regions and from the highlands of the southern peninsulas. The thermal equator also moved north of the geographical equator at this time, and during the long interglacial epoch that followed, lasting at least ten thousand years, the whole Northern Hemisphere enjoyed an equable climate, ranging from tropical to temperate conditions and devoid of great seasonal variations. The effect of this change must have been to limit the lines of migration toward the far south, and greatly to extend the course of dispersion towards the northeast and northwest. Or to put it more exactly: entry into South Africa was probably barred by the increasing cold, but as the influence of the southern glaciers did not extend as far north as the Indo-Mediterranean-Malaysian belt, the inhabitants of this region were doubtless free to wander east and west as before along the central latitudes. Nor did climatic conditions any longer prevent men from penetrating into the continental area beyond. Mountain masses still barred the way in the center, to be sure; but passages were open on either side; from the Mediterranean region into Europe, and from the Malaysian region into Asia. Above the Himalayan line the Tibetan plateau interposed itself between these Mediterranean and Malaysian emigrants and probably kept them for long ages apart. For this reason, and doubtless also because the maritime regions offered greater attractions to primeval man than the inland areas, the earliest lines of migration appear to have followed the Atlantic and Pacific coasts of the Eastern Hemisphere into the northern latitudes, where the shore lines of the Eurasian continent stretch out toward America. During the first and second interglacial epochs the two hemispheres were, indeed, practically coterminous in these parts. This was due to the fact that the level of the northern oceans was lowered at these times, leaving land-bridges exposed to view which have since become covered by the sea. As a result, the

Atlantic and Pacific routes of migration were continued along the northern latitudes into the Western Hemisphere. Toward the northwest, the British Isles then formed an integral part of the European continent, and from this peninsula, land-connections were in all probability extended through Iceland and Greenland to America. In the far northeast, Asia was likewise joined with America by what geologists call the Miocene bridge, which probably lasted into quaternary times; and after the Behring strait finally broke through, the Aleutian island chain still linked the two continents together along the Pacific. As far as climate and topography were concerned, during these interglacial epochs there was nothing, therefore, to prevent the Mediterranean and Malaysian emigrants from pushing northwestward through Europe and northeastward though Asia into America.

As the glaciers advanced successively from the arctic and antarctic regions, the climate and topography of the Northern and Southern Hemispheres varied in this way at least three times. After the third glacial epoch, however, the changes were less marked, until towards the close of the ice age, the configuration of the earth gradually assumed its historic form and the globe became divided as at present into temperature zones. The possibilities of dispersion during the glacial, interglacial and post-glacial periods may, accordingly, be generalized as follows: Each time the Northern Hemisphere was glaciated, the migrations of men must have been confined for the most part within the Indo-Mediterranean-Malaysian belt and the southern peninsulas of the Old World. During the genial epochs that intervened between the three great glacial movements from the north, the continental area was open to incursion on either side, the climate of the Northern Hemisphere was everywhere equable, and the topographic conditions were such as to encourage migration along the Atlantic and Pacific shores of the Eurasian continent into the arctic peninsulas of the New World. As the arctic glaciers became more and more restricted to the northern regions, primeval men were probably able to hold their own in the continental area and migrate east and west across Eurasia. But after the third glacial epoch, if not before, the Atlantic land-bridge was broken; so that henceforth access to America was only possible along the Pacific, by means of the Aleutian island chain.

Cave deposits, kitchen-middens and fossil remains mark the course of the dispersion of mankind in these different directions. The aboriginal inhabitants of the now separated continents and isolated islands of the globe also preserve certain distinguishing characteristics by which the lines of their respective ancestries can be traced back along these several routes to more or less definite points of departure about the Indo-Malaysian abode. There is archeological and ethnological evidence, therefore, to show that primeval men migrated

originally along the lines laid down by the climate and topography of the glacial periods. But these indications of the actual courses of migration are beyond the range of the immediate enquiry, and should, therefore, be reserved for separate consideration. It is sufficient for the present to have pointed out the possibilities of dispersion, which may be summarized in conclusion as follows: From the skeletal parts of Pithecanthropus we are assured that the pliocene precursor could walk; the nature of his food-quest affords the wandering motive; the widespread diffusion of quaternary culture convinces us of the fact of dispersion; and the data of geology define the routes provided by nature for the original migrations of mankind.

DISCUSSION AND CORRESPONDENCE.

THE FUNCTIONS OF A MUSEUM AND OF ITS DIRECTOR.

To the Editor:—Professor E. Ray Lankester, director of the Museum of Natural History, London, concluded an address on 'The Scope and Functions of Museums' at the opening of a new wing of the Ipswich Museum on November 8 with the following words:

> A county museum is not a place for children or school-teaching: it is not Noah's Ark or Madame Tussaud's waxworks, but a place for the delight of grown-up men and women. It should be full of the things which are the pride of those who care for the history and natural life of their countryside, and just as you do not use a picture gallery to teach the elements of drawing, but for the enjoyment of fine pictures, so your county museum must be for the enjoyment by your grown-up, educated people of the rarities of nature and of art, and not for the cramming of schoolboys and schoolgirls.

If a local museum is a place no better for school teaching than Madame Tussaud's 'chamber of horrors,' or if it only serves for the cramming of school-boys, so much the worse for the museum and its director. Neither has Professor Lankester a very high opinion of adult visitors, for in the same address he calls them 'innocent' and 'casual well-meaning.' Such sarcasm and assumption of superiority ill befits the director of a museum.

Surely a man who accepts a position such as the directorship of the British Museum of Natural History or the secretaryship of the Smithsonian Institution owes a definite duty to the public, and should not permit his impressions of his own dignity to interfere with the services for which he is paid.

Can you not, sir, secure for your excellent journal an article on 'The Scope and Functions of a Museum Director'?

A TEACHER.

SCIENTIFIC LITERATURE.

RECENT PSYCHOLOGICAL BOOKS.

The 'Dictionary of Philosophy and Psychology,' edited by Professor J. Mark Baldwin and published by the Macmillans, is a work of magnitude and importance. Only one of the three volumes has as yet been issued, but it suffices to give a correct impression of the character, range and quality of the undertaking. It falls between a dictionary and an encyclopedia, and in rather an eclectic fashion, some of the articles treating a small topic concisely while others fill many pages. In a first attempt of this character, with assistant editors and contributors scattered all over the world, it was obviously impossible to secure complete uniformity, and the frequency with which the editor's initials occur indicates that he realized the need of securing a unitary point of view. It is evident, however, that there is less agreement as to the fact and theory among philosophers and psychologists than is the case in other sciences. All the more credit must for this very reason be given to editor, contributors and publishers for producing what will for many years be the standard reference work in philosophy and psychology.

The French excel in the production of year-books, and 'L'année psychologique,' of which the seventh volume has recently been issued, is one of the best of them. The preparation must involve great labor on the part of the editor, M. Binet, for the researches, filling 558 pages, come chiefly from his laboratory at the Sorbonne, and the reviews, filling about 150 pages, are nearly all written by his own hand. The bibliography, containing 2,627 titles, is, however, reprinted from that of the 'Psychological Review,' and we fail to find reference to this fact. As there is no psychological journal in France, this work is essential to those who wish to follow the progress of experimental psychology in that country.

M. Pièrre Janet's 'Etat mental des hystériques' was translated into English by the late Mrs. Hiram Corson and is now published by the Putnams. The book appeared in French some nine years ago, and the need of the present English version is not quite obvious. It was sufficiently accessible to scientific men in the original, and it is to be feared that if the thousand copies which American publishers regard as the minimum sale that warrants acceptance are distributed, they will fall chiefly into the hands of those whom the translator call 'hystericals.' M. Janet has made some careful observations, and in his explanations lays great stress on subconsciousness, split-off ideas and the like. The French have done so much more work in these directions than others that we should perhaps accept their theories. But conservative scientific and medical men prefer to wait.

'Intuitive Suggestions,' by Mr. J. W. Thomas, bears the respected imprint of Messrs. Longmans, Green & Co., and opens the question as to whether publishers accept any responsibility for their books, beyond the financial one. The author places on his title-page the text: 'And God said, Let there be light; and there was light.' We fear not, if the reference is to the contents of the book. The author expects London business men to soar 'above the smoke and din to seek their homes in the country,' not in flying machines but by 'levitation.'

THE PROGRESS OF SCIENCE.

THE CARNEGIE INSTITUTION.

One of the most noteworthy events in the history of science was the bequest of James Smithson, an Englishman dying in Italy, in 1829, of about $500,000 to found at Washington 'an establishment for the increase and diffusion of knowledge among men.' Equally important is the gift of Mr. Andrew Carnegie of $10,000,000 to establish in Washington an institution for the encouragement of 'investigation, research and discovery.' These two foundations represent more than an addition to the sum annually spent on scientific work. They stand for the spirit of science, not confined by place or buildings, titles or degrees. In foreign countries we are often called worshipers of wealth and ostentation; in reply we need only point to the Smithsonian and Carnegie institutions, situated in the national capital, but extending throughout the country and beyond, quietly and powerfully representing the highest ideals of knowledge and research.

The Smithsonian Institution under Henry and Baird fostered science in many directions, having been more or less a factor in the establishment of the National Library, the Weather Bureau, the Geological and Coast Surveys and the Fish Commission. It still has under its charge the National Museum, the Bureau of American Ethnology and the Zoological Park. The Carnegie Institution with twenty times the resources of the Smithsonian will henceforth be a great influence for the advancement of knowledge. The founder states that the primary object is the promotion of research, and specifies several directions in which work will be undertaken. The Institution will probably supersede the Washington Memorial Institution in the function of utilizing for advanced work the resources of the government at Washington and elsewhere. It will also aim to increase the efficiency of universities and other institutions by providing funds for investigations and for fellowships. It will assist in the publication of scientific work. It may give salaries and pensions to permit the continuous prosecution of research. Mr. Carnegie shows much insight in particularly specifying as one of its objects 'to discover the exceptional man in every department of study, whenever and wherever found, and enable him by financial aid to make the work for which he seems specially designed, his life work.'

This is, indeed, the great need of science—to find the men. Given the man and there is no danger but that the research, the discovery and the publication will follow. What is essential is to secure for research the men best fitted for it. Good men are needed for all kinds of useful work; but on the whole the business man, the lawyer or the physician is less likely to contribute to the general welfare than the investigator. But the investigator is exactly the man whose profession is most insecure. He never depends on his scientific work for his support; he must earn his living by teaching, by administrative work or the like. A good novel or a good picture has market value, a good research has none. The author is not only unpaid, but is fortunate if his paper or book can be properly published without expense to himself.

The number and quality of men engaged in scientific work can apparently

be increased best in two ways; by permitting a larger number of young men to carry on work long enough to be eligible for national selection, and by offering certain prizes for those who reach the highest efficiency. Our universities now provide a considerable number of scholarships and fellowships; they should be increased, but even more than these we need offices, such as the secretaryship of the Smithsonian Institution, that will attract young men to science as a profession and provide adequate rewards and the best opportunities for those whose work is most fruitful. It has already been pointed out in these columns that while a lawyer may become a judge, a clergyman a bishop, a business man a millionaire and the like, there are no similar rewards for a scientific man or a university professor. At a comparatively early age he receives the maximum salary of from three to five thousand dollars, and no further advancement is possible—unless he leaves scientific work to become an inventor or a college president.

The directorship of the Carnegie Institution will be one prize, but its duties will be largely administrative. The trustees of the institution selected by Mr. Carnegie are men of tried administrative ability; but they are too busy and too widely scattered over the country to attend to the details of the scientific work of the institution. We should view with much satisfaction the establishment of a board of scientific directors who should at the same time be research professors, spending part of the year at Washington and part at their present universities or institutions, receiving ample salaries and having the best facilities for work. The honor of selection for this position and a salary comparable to that which may be earned in other professions would add great attractiveness to science as a profession and serve as a continual stimulus to scientific research.

There are, however, many ways by which the great resources of the Carnegie Institution can be utilized for the benefit of science, and the trustees are certainly competent to select the best methods. There is no doubt but that the institution will greatly aid in giving the United States a leading place among the nations that are contributing to the advancement of science, and will tend to make Washington one of the three or four chief scientific centers of the world.

MEETINGS OF SCIENTIFIC SOCIETIES.

The meeting in Chicago at the beginning of the year of the American Society of Naturalists and of the national societies devoted to the biological sciences was of more than usual interest. It marked the establishment of convocation week. At the instance of the American Association for the Advancement of Science our leading universities have set aside for the meetings of scientific and learned societies the week on which the first day of January falls, greatly facilitating those meetings of scientific men, which are among the most potent factors in the advancement of science. The meeting at Chicago was also noteworthy because it was the first to be held west of the Atlantic seaboard. It will be remembered that the American Association met this year for the first time west of the Mississippi, and our two great scientific societies and centers of affiliation have thus in the same year become truly national in character. The remarkable development of science in the central states within recent years is witnessed by the fact that the meeting at Chicago was the largest and probably the most important ever held by the affiliated societies. There were over 300 scientific men in attendance, and over 250 scientific papers were presented. It is of course impossible to give here any adequate account of this great mass of scientific work. The annual discussion, in which Professors Minot, Davenport, McGee,

Trelease, Birge, Forbes and Cattell were the speakers, considered the interrelations of our scientific societies. There was a consensus of opinion that we should develop local centers for scientific meetings, but must have also national societies, and that these should be united in a great association representing the whole country and all the societies. The practical outcome was the decision of all the societies to meet next winter in Washington.

With the American Society of Naturalists met at Chicago the national scientific societies devoted to morphology, physiology, anatomy, bacteriology, psychology and anthropology. The American Chemical Society met at the same time at Philadelphia with an attendance of over two hundred and a full program. The Society now contains over 2,000 members, and is perhaps the strongest and best organized of our special scientific societies. It conducts an excellent journal, has numerous local branches which hold frequent meetings, and is affiliated with the American Association. At the recent meeting Professor F. W. Clarke gave the presidential address, dealing with the outlook for chemistry in the future viewed in the light of the past, and Professor C. F. Chandler lectured on the electrochemical industries of Niagara Falls. The Geological Society of America also met during convocation week, the place being Rochester, N. Y., and the time December 21 to January 2. The president, Dr. Charles D. Walcott, gave an address on 'The Outlook of the Geologist in America,' and the program contained the titles of some thirty papers. The Astronomical and Astrophysical Society of America met at Washington, while the American Mathematical and Physical Societies and the Society for Plant Morphology and Physiology of the Eastern States met in New York. All these societies will meet next winter with the American Association for the Advancement of Science at Washington during convocation week, where there will be a congress of American scientific men surpassing in size and importance all its predecessors.

WIRELESS TELEGRAPHY.

As all our readers know from the daily papers, Mr. Marconi has succeeded in transmitting wireless signals across the Atlantic from Cornwall, England, to St. John's, Newfoundland. The electrical waves were received at St. John's by a long wire suspended by a kite and by means of a telephone, presumably through the mediation of a coherer. A detailed description of Mr. Marconi's latest apparatus has not been published. However, some results obtained by him several months ago show that his apparatus has been improved in its selective action, and this latest achievement shows that little remains to be done in the way of increase of power. Nevertheless there seem to be decided limitations to the utilization of wireless telegraphy; it is at present much slower than the standard Morse apparatus using a wire, the receiving operator cannot interrupt the sender but must wait patiently until the message is finished, there is no assurance of secrecy, and but one system can be operated at a time within the limits of its range.

A map of the world showing all cable connections is a very complicated affair, and the supplanting of these cables by wireless apparatus is out of the question, at least until the Marconi system is evolved into something very different from what it now is. The facts may be made clear by an acoustical analogy. The ordinary confusions of sounds in a stock exchange is bad enough, but if the manifold and characteristic shadings of voice were reduced to a monotony of mere clicks and if the resolving or selective power of the listener's ear were at the same time reduced many thousands of times the confusion would become hopeless indeed. The loudness of each speaker

would have to be reduced, and each speaker and his listeners would have to occupy a certain space to the exclusion of all others. Under these conditions a given speaker's demonstration of his power to make himself heard over a distance of many miles would scarcely be looked upon as of practical importance, unless indeed it were seriously questioned whether his associates might have the right to restrict the exercise of their vocal powers. The proper field of wireless telegraphy appears to be the overspreading of limited areas, especially areas of water, with telegraphic facilities.

AS SEEN IN GERMANY.

THOSE who wish to know something of the educational (educational in the broadest sense of the word) advantages enjoyed by the eastern United States can not do better than to consult Dr. A. B. Meyer's memoir on the museum of this section. Dr. Meyer came here in the summer of 1900 to obtain all possible information concerning our museums, their construction, arrangement, methods of installation, and the scope of his inquiries was extended to libraries and art museums. The results of his observations are being published by the Royal Museum of Dresden and the second part of the memoir, for it amounts to that, has recently been issued and comprises one hundred quarto pages with fifty-nine illustrations. It is devoted to the museums, libraries, Art Institute and University of Chicago, and Chicago has every reason to feel gratified at the showing made in this paper. At the head of the text stands Chicago's motto 'I will' (*Ich will*), and Dr. Meyer has frequent occasion to refer to the energy and creative power of this million-inhabited city, if one may paraphrase the author, of the west. In fact we doubt if many in Chicago, to say nothing of those living in other portions of the United States, realize the rapid strides she has made in—using the term in its widest sense—great educational institutions. Like the former part this gives a brief history of each institution considered, its origin, aims, endowment, expenditure, and the methods by which it endeavors to accomplish the desired ends. Then follows a detailed account of the collections, be they of natural history, art or books, with special notice of any original or important device for installation, labeling or cataloguing. As Dr. Meyer is not only a museum director, but one acquainted with the mechanical details of the various branches of work, and one who has devoted much time and thought to the construction of cases and methods of installation, he here speaks by the book.

The illustrations show an exterior view of each of the buildings considered, and noteworthy features of the interior, as well as of special cases and fittings. There are also in most instances plans giving the arrangement of the various floors, and sections showing special modes of heating or ventilating, and of the construction of modern iron frame buildings.

Dr. Meyer considers that the existence of the Field Columbian Museum should stimulate rather than deter the growth of the collections of the Chicago Academy of Sciences, and that not only do these two institutions supplement one another, but that two museums are a necessity for a city which like Chicago covers an area of 180 square miles. The plans for the Academy of Sciences are well conceived, and it would be well to consider them carefully in the event of erecting a new and permanent building to replace the present Field Columbian Museum. As we all know this was taken for a museum in default of any other available building, and Dr. Meyer may well criticize its halls as being on too large a scale to fit them for the best arrangement of a museum. One of the results of this is to bring about a somewhat heterogeneous arrangement of the

collections and to place in juxtaposition, or to include in one view through lack of division, very different classes of objects. It is hoped that the time may soon come when less money shall be spent on specimens for exhibition and more in research and publication. Beyond a certain point the mere exhibition of material can not be advantageously carried, for the confusion of mind created by a multitude of objects defeats the educational effect which a museum should exert.

The libraries of Chicago—the John Crerar, the Newberry and the Public Library—are looked upon as sustaining much the same relations to one another as do the museums, each having its own field, and one supplementing the other, while the friendly rivalry between them is resulting in the accumulation of a vast number of books and pamphlets. The combined entries of these three libraries now amount to 650,000, and at the present rate of growth, they will, in twenty-five years, reach a million, the present size of the library of Berlin, which ranks third among the great libraries of the world.

One quarter of the present volume is devoted to the University of Chicago, treating in detail its many peculiar and progressive features with special reference to its museums and laboratories. In the former the inclusion of paleontological collections with those illustrating the modern life of the globe is regarded as an excellent feature, and this is no doubt true to a great extent. Still such a union is much more feasible in a small than in a large museum and also much depends upon the point of view, upon whether it is desired to show the relations of all living things to one another, or the successive faunas and floras of the globe and the steps by which the existing order of plant and animal life has been reached.

In conclusion Dr. Meyer pays an eloquent tribute to Chicago, for which he predicts a great future as a center of science, literature and art.

IMPORTANT PALEONTOLOGICAL DISCOVERIES.

The origin of the proboscideans, the Mammoth, Mastodon and Dinotherium, has long remained an unsolved problem, and until recently no form was known below the lower Miocene. Señor Ameghino thought he had discovered the ancestor of the group in the Santa Cruz formation of Patagonia, but his views were not shared by others, and the late Professor Cope believed, with much to support the belief, that the founder of the family would be found in Asia.

During the summer of the present year Dr. C. W. Andrews, of the British Museum, was engaged in collecting in the Fayûm, Egypt, obtaining numbers of vertebrates from deposits believed to be of Eocene or Oligocene age, most probably the former. Among the mammals represented was a small and primitive species of Mastodon, named *Palæomastodon beadnelli*, characterized by the simple structure of the last grinder and by the fact that no less than five teeth were in use at once on either side of the lower jaw. Other known species of Mastodon have but three teeth in use at any one time on either side of the lower jaw, so that this indicates an animal of a much more generalized type. More than this, Dr. Andrews obtained numerous specimens of another animal, named *Meritherium*, about the size of a large tapir, having large and tusk-like incisors and molars, whose structure suggests that of the teeth of the Dinotherium. This creature Dr. Andrews considers to be the long sought ancestor of the Mastodon type of proboscideans. The fauna of these Egyptian beds is quite different from that of deposits of corresponding age in Europe, and the few species so far discovered hint that a more complete knowledge will throw much needed light on many obscure questions in geographical distribution. The indications are that prior to the Miocene southern Africa was an exten-

sive and isolated continental area, or, that at least it had no connection with Europe.

In the United States particular attention has been given to working out the pedigree, in the fullest sense of the word, of the horse, and in doing this the American Museum of Natural History has been especially favored by the gift of a considerable sum of money for that purpose. Under the direction of Professor Osborn parties have been successful in Texas and northeastern Colorado in obtaining unusually complete specimens of early horses. In the former locality Mr. Gidley discovered the fossil remains of a small herd of Miocene horses of the genus *Protohippus,* while in Colorado Messrs. Matthew and Brown obtained very complete specimens of Anchitherium from the Upper Miocene associated with at least three species of horse-like animals that represent side branches of the equine tree. The disappearance of horses from North America is a very singular fact; they developed here, literally growing up with the country, and they ranged from the Atlantic to the Pacific and from Alaska to Patagonia. It is even probable that they migrated to Asia at the time the Mammoth was making his way eastward, and yet they disappeared completely. It would seem that Dr. Jordan's three laws of distribution need the addition of another to explain the dying out of animals. It can not be said that a series of species that developed in a given region was not adapted to it, and the rapid increase of horses that run wild on the pampas of South America and the plains of the west shows that the modern horse was perfectly fitted to those regions.

One more important discovery during this year was the finding by Mr. Barnum Brown, while collecting for the U. S. National Museum in the Trias of Arizona, of plates of a huge labyrinthodont, at least as large as those European species restored by Waterhouse Hawkins in the likeness of gigantic frogs, for their tails were not then known. The specimens have been identified by Dr. Fraas as belonging to the genus *Metopias,* and he regards this of special importance as showing that the beds in Arizona correspond to the historic Keuper of Europe, that genus of amphibians being confined to that formation.

SCIENTIFIC ITEMS.

We regret to record the deaths of Mr. Clarence King, the eminent geologist; Sir William MacCormac, the British surgeon; Professor Aleksandr Aleksandrovic Kovalevskij, professor emeritus of zoology at the University of St. Petersburg, and Dr. Arthur König, associate professor of the physiology of the sense organs at the University of Berlin.

The newly elected presidents of the scientific societies, whose meetings are described above, are as follows: The American Chemical Society, President, Ira Remsen, Johns Hopkins University; American Society of Naturalists, Professor J. McKeen Cattell, Columbia University; American Morphological Society, Dr. H. C. Bumpus, American Museum of Natural History; American Physiological Society, Professor R. H. Chittenden, Yale University; Association of American Anatomists, Professor G. S. Huntington, Columbia University; American Psychological Association, Professor E. C. Sanford, Clark University; American Society of Bacteriologists, Professor H. W. Conn, Wesleyan University; The Society for Plant Morphology and Physiology, Professor M. V. Spalding, University of Michigan; The Geological Society of America, Mr. H. N. Winchell, Minnesota.

The Avenue of Royal Palms *(Oreodoxa oleracea)* in the Botanical Gardens at Rio de Janeiro. From a Photograph by M. Ferrez.

THE POPULAR SCIENCE MONTHLY.

MARCH, 1902.

THE PALM TREES OF BRAZIL.

BY PROFESSOR JOHN C. BRANNER,

STANFORD UNIVERSITY.

OF all the graceful, beautiful and bizarre plants that grow in the tropics none are more graceful and none give such character to tropical vegetation as do the palms. Varied in form and size, adapting themselves to a wide range of elevation, sweeping up from the sandy shores of the sea across marshes, flood-plains and well-watered forests, over barren and thirsty deserts to the subalpine slopes of lofty mountains, they are, above all plants, the ones that give character and picturesqueness to every tropical landscape. And there is no place in the world where one finds a greater number of species of palms or where they grow more abundantly or more luxuriantly than they do in Brazil, and above all, in the valley of the Amazonas.

No good word is needed for the grace and stately beauty of palm trees. Those of us who live in the temperate regions already appreciate these ornamental plants to such an extent that there is now an established business in the manufacture of artificial palms for decorative purposes, to say nothing of their extensive cultivation by gardeners and seedsmen. As useful plants in other ways we know, as a rule, but little about them. In their native tropics palms are better thought of; the people fully appreciate them as ornamental plants, especially for large landscape effects. This is well shown in the use of the royal palms in Brazil. One of the most impressive sights in the sightly city of Rio de Janeiro is the avenue of royal palms at the Botanical Gardens. It is impossible to convey an idea of the grandeur of these enormous trees with their trunks as round and smooth as if they had been

turned on a lathe, tapering from base to summit and crowned by clusters of plumy fronds more than a hundred feet from the ground. I do not know just how old these trees are, but a hundred years or so, I have been told; nor how tall they are, but that one can see for himself; and the height is certainly impressive. The kind of palms forming this particular avenue *(Oreodoxa oleracea)* has been extensively planted in parks and in public and large private grounds since the stately groups at the Botanical Gardens came to be appreciated more than half a century ago. To-day these trees are to be seen in most of the capitals and larger cities all over Brazil.

But the Brazilians think of palms more seriously as useful in other ways than as landscape ornaments. Indeed, to the traveler in the interior of Brazil, one of the most striking things about palms is the great number of uses to which they are put, uses extending to all parts of the plant. It is a matter of great importance in the tropics that plants bear their fruits and yield their other products with but little or no labor on the part of man, and this the palms all do. To mention all their uses in a short article is quite impossible. It is said of the coco* palm, for instance, that it has a use for every day in the year, and whether this be true or not, it is near enough the truth to illustrate the point; and it is no extravagant statement of its virtues. Out of more than a hundred species of Brazilian palms upon which I made notes there is hardly one that has not some special and important use.

To the casual observer it might appear that palms are plants of such marked characters that there would be no difficulty in distinguishing the species. At least that was my own impression when I first walked through an Amazonian forest and observed the apparently wide differences between them. But as one's acquaintance with palms widens he finds them to be very like other organisms in their similarities and dissimilarities.

The Palm Trunk.—Palms vary enormously in size, shape, habit and habitat. The largest are the royal palms which reach a height of nearly two hundred feet with a perfectly straight, smooth and symmetrically tapering trunk over a meter in diameter at the base. The smallest are the *Geonomas* and certain species of *Bactris,* slender delicate plants but little more than a meter in height, with a trunk not larger than an ordinary lead pencil. Still others have no trunks at all above the ground, but the leaves and fruits rise from a short stock concealed beneath the soil very like a bulb.

The *jacitára (Desmoncus)* has a trunk the size of a man's finger and a length of a hundred feet or more, a form that is unable to stand erect, but sprawls or clambers over other plants like a vine. Some

* *Coco,* not *cocoa,* is the correct form of this word.

palm trunks are smooth while others are thickly covered with repulsive spines often of enormous size, and still others are clothed with mats of long tough fiber resembling masses of tangled and broken twine.

Certain species have trunks of uneven size, swollen here or there. These bellied palms, as they are called in Brazil, usually have the swollen part at some fixed place in the trunk. This is true of the *paxiuba barriguda (Iriartea ventricosa)* and of the *Acrocomia,* but at Assuncion, Paraguay, I found the swollen portions of the trunk of a palm locally called Bocadjá now near the base and now near the summit and another time near the middle. Some palm trunks are as smooth as if tooled, others, like the coco, are more or less ribbed. These ribs run round the trunk, and on some trees they are so close together that the whole trunk is notched with them. The ribs are really only leaf scars,

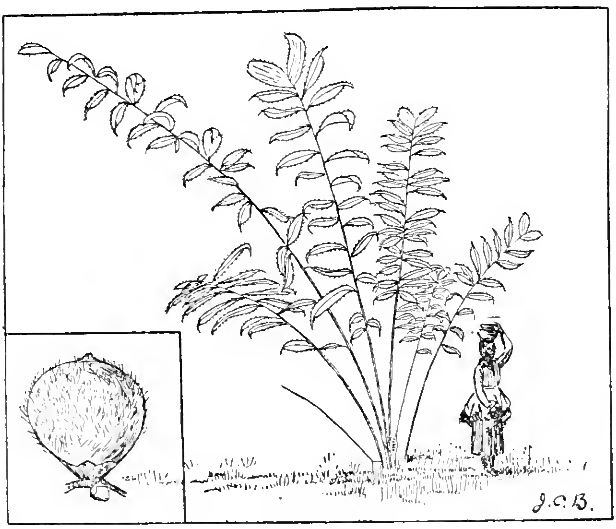

FIG. 2. A TRUNKLESS PALM (*Astrocaryum humilis* C.); FRUIT NATURAL SIZE.

and on some species they are so far apart that the stems appear to be jointed like a bamboo. The ribbed trunks and smooth trunks, however, are noticeable only on palms that shed their fronds freely after they mature. In some cases the petiole breaks off two or three feet from the trunk, leaving it bristling with the jagged stumps of the petioles. In the accompanying illustration of the jupaty it will be seen that both conditions sometimes prevail with the same species.

Some trunks are thickly covered with spines. These spines vary in size from a few millimeters to half a meter in length. They seldom grow on the leaf scars, but usually cover the spaces between them.

Palm trunks may be either straight or crooked, but the habit of a species in this respect is pretty constant. For instance, the royal palm

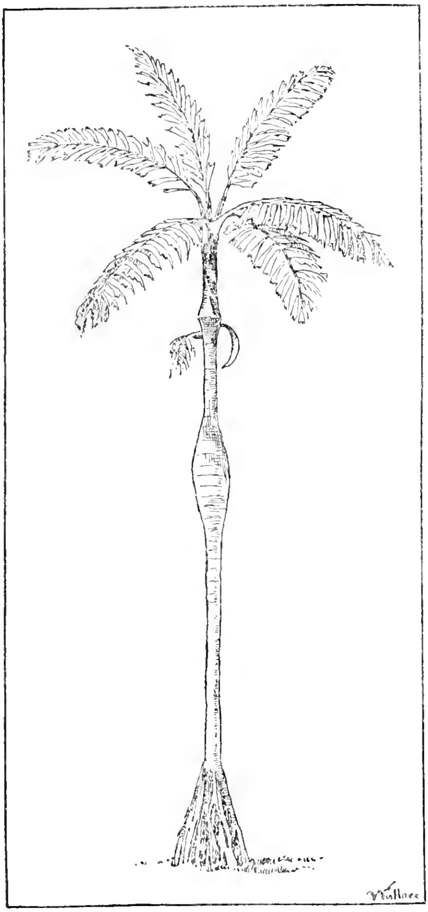

FIG. 3. *Iriartea ventricosa*, A BELLIED PALM (AFTER WALLACE).

always has a straight trunk; the clambering species never have the trunk straight, and the full-grown coco palms have the trunk somewhat crooked. A singularity of the growth of palm trunks is that, with the exception of the 'bellied' trunks, they attain their full diameter while quite young—before, indeed, they set out to grow upwards. In other words, a palm grows endwise, as it were, but does not grow in diameter like the exogenous plants. It is therefore necessary that a palm should start on a broad base if it is to reach great height and great size. For this reason many of them when young look as if their fronds were growing from the top of a gigantic turnip-like stock. In some species as a trunk grows older it constantly strengthens its foundations by putting out rootlets just above the uppermost ones, very much like those starting from the lower joints of a cornstalk, and these roots continue to put forth until a compact and exceedingly tough support is built up about the trunk. In the *paxiuba* palm this buttress is one of the strange sights of the vegetable world.

Fig. 7 shows the remarkable rooting of the *paxiuba* (*Iriartia exorrhiga*). At the lower left side of the plate the details of one of these trunks are shown. These palms seem literally to be off the earth, for the trunk proper can scarcely be said to touch it. The figure in the upper left hand corner shows how the young *paxiuba* gets its start.

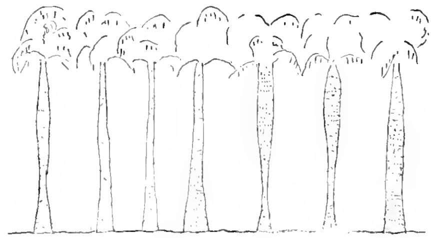

FIG. 4. VARIATIONS IN THE FORM OF THE TRUNK OF *Bocadja*, ASUNCION, PARAGUAY.

After the nut sprouts from the ground a rootlet starts from the young trunk a few inches above the soil and grows downward to the earth; then another and another starts out a little higher up, each growing down into the ground. As the tree increases in size these roots continue to grow outward and downward always at an angle that will most effectively brace the trunk. I have seen the roots starting from the trunk seven and a half feet from the ground.

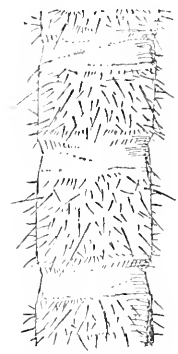

FIG. 5. THE SPINY TRUNK OF A *Bactris*.

Structure of the Trunk.—The structure of the palm trunk is always the same in that it is made of fibro-vascular or horny bundles and parenchyma or pith; as a rule, too, the horny bundles are grouped together near the surface of the trunk, while the central portion holds most of the pith. Seen in cross-section the palm trunk is very like the stalk of the Indian corn. There is, however, a marked variation among palms in the direction of these bundles through the stems, for in some they ascend the trunk in a vertical plane while in others they take a spiral direction, not keeping parallel with each other but crossing one another in a bewildering maze. As these hard bundles are what give strength and resistance to the palm trunk, it will be seen that the possibility of splitting some of the trunks must depend upon the direction of the fibro-vascular bundles. In the *Iriartia* or *paxiuba* the fibro-vascular bundles lie in a vertical plane and are parallel, so that a section of the trunk of this palm splits with ease, and for this reason it is extensively used for umbrella handles, walking canes and such like purposes. Some of the palm woods admit of a beautiful polish, and, in these cases, the winding directions of the bundles cause them to be cut off at various angles and render the ornamental pieces made of them very beautiful. The fibro-vascular bundles vary greatly in color in the different palm trunks, some of them being nearly white, others amber-colored, others black and still others dark brown; most of them have a waxy, horn-like luster, and all of them are, when mature, exceedingly hard.

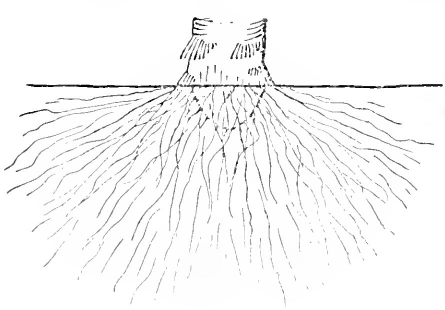

FIG. 6. THE ROOTS OF AN ORDINARY PALM.

The purely mechanical office which these fibro-vascular bundles perform is necessarily of the utmost importance in giving character and form to the trunk. They extend also from the trunks out into

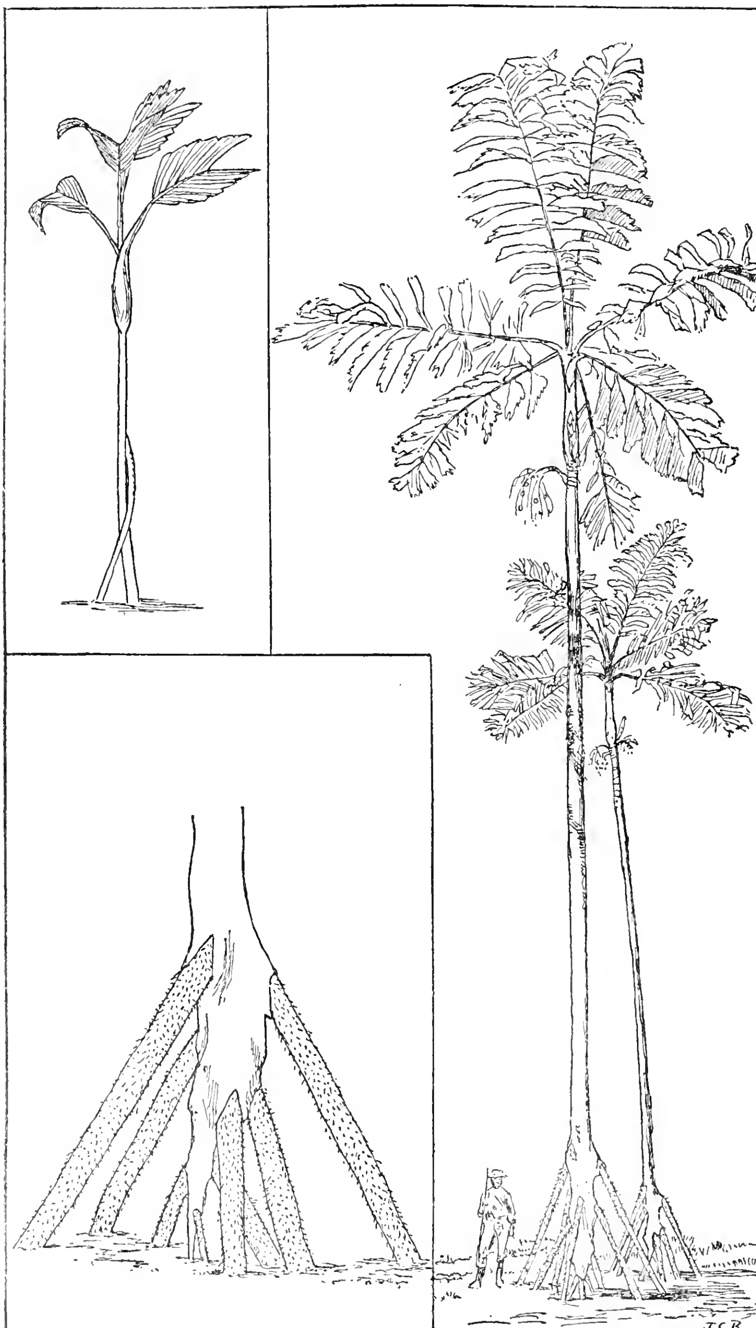

FIG. 7. *Iriartea exorrhiza*, AMAZONAS.

the fronds to their very tips. When the size of the leaves of some of the Amazonian palms is recalled—as large as a man can carry—it will be recognized that these bundles must be very strong.

The fibro-vascular bundles pass out from the palm trunk into the fronds. In Gray's text-book of botany a short longitudinal section of a palm trunk is shown, in which these bundles are represented as coming to the surface very much at random. As a matter of fact they reach the surface only at the leaf scars.*

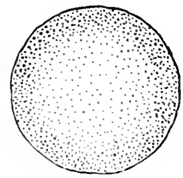

Fig. 8. Cross Section of a Palm Trunk showing the usual Arrangement of the Fibro-vascular Bundles.

The most important use to which palm trunks are put is probably the manufacture of rattan or 'cane' used to bottom chairs. The rattan palm *(Calamus)* does not grow in Brazil, but the Jacitára and Urumbámba *(Desmoncus)* are palms of similar habits, though they do not seem to lend themselves to this sort of use as readily as the *Calamus*.

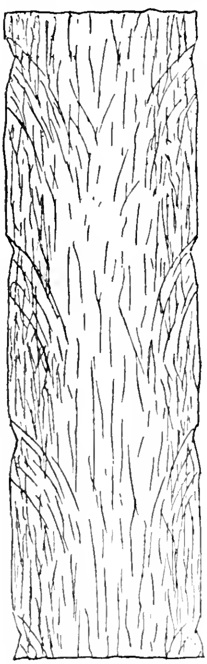

Fig. 9. Section of a Palm Trunk showing the Relation of the Fibro-vascular Bundles to the Frond Bases.

Foliage.—The foliage of the trunked palm, unlike that of most plants, is all at the summit of the single stem.†

The fronds of most of them form a compact symmetrical cluster, but there is one kind of *bacába (Oenocarpus distichus)* that has its fronds arranged in a single plane like a gigantic open fan.

The gracefulness of palms is mostly due to the symmetry of the plants combined with the flexibility of the fronds and leaflets. In the length and size of their leaves many of the palms surpass all other forms of vegetation. In detail the foliage varies quite as much as do the trunks. The palmate leaf from which the 'palm leaf fans' are made is familiar to every one. Some of the palmate leaves, however, reach an almost incredible size. The great *murity* of the Amazonas region often has its palmate leaves so large that a man, unaided, cannot lift a single leaf. The palmate leaves are entire, as a rule, but there is at least one species that has the leaf deeply bifid or split down the middle into two equal parts.

* The course and growth of the fibro-vascular bundles in palms. 'Proc. Am. Phil. Soc.,' 1884, XXI., 459–483.

† The branching doom palm of Africa *(Hyphaene thebaica)* is the only exception to this rule. There is an Areca that forks near the base, and the date palm puts out shoots at or near the base of the trunk.

The *ubussá (Manicaria saccifera)* of the lower Amazons has a kind of frond found, I believe, in no other palm; its leaf in general outline is like that of a pinnate leaf—say like that of the coco or date palm—but, instead of being divided, like the pinnate frond, it is entire.

Most of the palms have the pinnate or feather-like leaves. There might seem to be but little opportunity for variation in such fronds, but the variation is really very great, although at first sight it is not striking. Perhaps the largest of the pinnate fronds are those of the

FIG. 10. *Œnocarpus distichus*, A FAN-SHAPED PALM OF THE LOWER AMAZONS.

jupaty (Raphia tædigera (Fig. 11) which often have a length of 45 feet. It might not appeal to one but little familiar with palms, but it is a fact that the attitudes of the fronds and leaflets of a palm tree are thoroughly characteristic. The accompanying diagram (Fig 12) will give an idea of what is meant. The frond of a given species has a certain habit of hanging, and that habit is constant and characteristic of the species. There may be—there always is—some difference of attitude between the young leaves and the old ones, but even these differences are constant. Occasionally, however, one may be a little puzzled at the attitude of the fronds of a palm growing under unusual

FIG. 11. *Raphia tædigera*, THE JUPATY OF THE LOWER AMAZONS.

conditions so that the whole plant is dwarfed.* The above remarks apply to a frond or rather to the midrib of a palm when looked at in cross-section. When considered in cross-section the plumose fronds vary in a striking manner. The leaflets are arranged upon the midrib so that they may be in two rows or in four or six or more rows—half on one

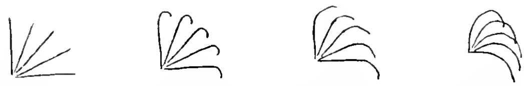

FIG. 12. DIAGRAMMATIC REPRESENTATION OF THE POSITIONS OF PALM FRONDS, HALF OF THE HEAD BEING SHOWN.

side and half on the opposite side of the petiole. Seen in cross-section these latter take on one of the forms shown in the following diagram or one of many other combinations. These differences between fronds depend to a great extent on the manner in which the leaflets are attached to the midrib. For example, the leaflets may lie in a single plane growing straight out from the opposite sides of the midrib or they may lie in two, four, six or eight planes that meet along the midrib.

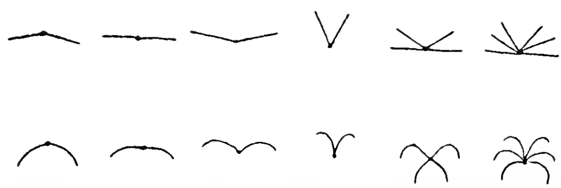

FIG. 13. DIAGRAMS OF CROSS-SECTIONS OF PALM FRONDS, SHOWING THE ARRANGEMENT OF THE LEAFLETS.

The fronds have, in addition to these peculiarities, certain habits due to the shapes of the midrib. A midrib that is broad at the base and continues relatively broad to the end is compelled to remain, as to cross-section, in a horizontal position; but if a midrib is broad at the base and gets rapidly narrower toward the end it cannot maintain itself in a horizontal position, but twists a fourth of the way round and at the end lies on edge. Sometimes this twisting goes to such an extent that the frond is quite inverted. The cross-sections of the midribs of palm fronds are characteristics to which but little attention seems to have been given by botanists.

Every palm leaf begins its life at the apex of the trunk—the newest

* Since observing this peculiarity of palm fronds, I have frequently seen something of the same kind in the great 'deadenings' of the South and Southwest. Many species of trees are readily recognized at a distance by the attitudes of the dead and broken limbs: the limbs of the black oak stand up nearly straight; those of the black-jack hang down and curl under, while those of the post oak are full of 'elbows.'

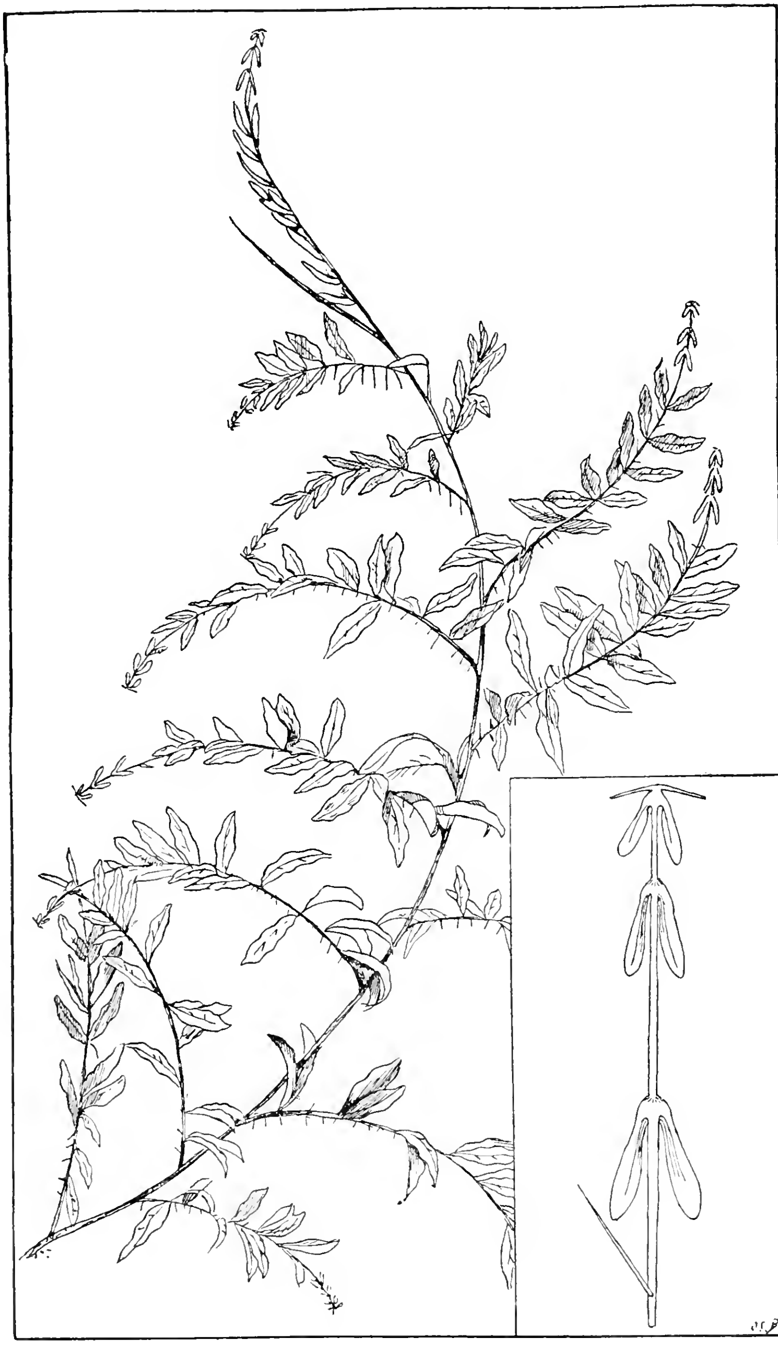

FIG. 14. URUMBÁMBA OF THE UPPER PARAGUAY—*Desmoncus cuyabaensis* BARB. ROD.

and uppermost of all the leaves—and ends its life as the lowest in the cluster. The shape and size of the cluster of leaves vary somewhat with the age of the tree, but some species differ greatly from others in this respect. Species like the *assaí*, the *palmito* and the royal palm have long petioles folding completely around the trunk, and shed the lowest leaves as fast as these leaves pass maturity. The clusters of fronds upon palms of this kind are always fresh looking, for they never have dead fronds dangling against their trunks. (See Fig. 1.) Certain other species have the habit of retaining the dead or half-dead fronds for a certain length of time, and these fronds, as they get older, bend downward more and more until they lie against the trunk of the tree. Such palms have nearly round clusters of fronds. The great forests of *carnaúba* or *carandá* palms along the Paraguay river look like forests of gigantic clover blossoms growing on straight stems.

The fronds of palms are extensively used by the lower classes in the tropical parts of South America for thatching their houses. Along the seashores, where the coco palms are grown, the leaves are cut as regularly as the nuts, and are used for covering the roofs and often for making the walls of the humble homes of the fishermen. In the Amazonas valley the entire leaves of the *ubussú* are best adapted to thatching; for this purpose they are frequently carried a hundred miles or more in canoes.

The young leaflets of palms are widely used in the manufacture of certain kinds of cheap straw hats. The leaflets of the *tucúm* palm yield an excellent fiber—one of the strongest known.

On account of certain peculiarities of its leaves I may here mention the *jacitára (Desmoncus)*, the long, slender, clambering or sprawling palm already spoken of. The *jacitára* is not precisely a climbing palm but it comes as near to it as a palm can come. Its full-grown stem is hardly larger than a lead pencil but it reaches a length of a hundred feet or more, and it is therefore impossible for it to stand upright. Shortly after it starts from the ground it topples over and rests against whatever happens to be at hand. It has no tendrils and does not wind about its supports, but the structure and habits of its fronds contribute effectively to its ability to support itself against or upon its neighbors.

The accompanying illustration (Fig. 14) shows the growing end of one of these clambering palms, and beside it is shown the structure of the tips of the fronds. The recurved hooks at the frond tip are quite stiff and are fastened to the midrib with thickened inflexible joints. In the unopened or embryonic fronds the leaflets all point forward toward the tip or external end of the leaf. At the end of these undeveloped leaves are three or four pairs of leaflets, which, like all the rest, point forward. When the frond unfolds, the terminal

pairs of leaflets, instead of developing as leaflets, turn gradually backward, thicken and stiffen at the base and thus form three or four pairs of hooks by which the plant is drawn slightly forward and supported by whatever other plant these hooks happen to seize.

Jacitára bears bunches of small nuts about the size of ordinary grapes, but, so far as I know, they are not utilized. The trunks are used in some parts of South America as withes for binding together the poles of which fences and some houses are built, and likewise for chair bottoms and baskets. When the *jacitára* grows in the deep dark forests, its trunk reaches a great length. In the southern part of the State of Bahia it grows upon open prairies where it has to depend upon itself for support. Here it grows in thick clusters, and does not reach a length of more than ten or fifteen feet.

Palm Fibers.—One of the most useful products of palms is their fiber. In his excellent work on fiber-producing plants Mr. Dodge mentions fifty-six palms that yield valuable fibers.* Most of the fibers furnished by palms come from growths along the sides of the petioles near their bases, where they look like frazzled edges of burlap or some other coarse cloth. These fibers, however, are produced in quantity by certain species only.

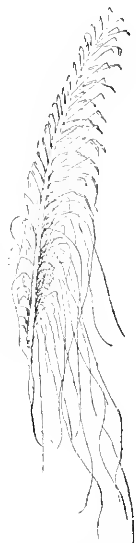
Fig. 15. A Piassába Frond with its Fibers.

The most remarkable of the fiber-producers is the *piassába* palm *(Leopoldina)* of which there are two species—one grows on the dark water tributaries of Rio Negro in the Amazon valley, the other grows not far from the seacoast north of the city of Bahia and also in the interior of the southern part of the State of Bahia and in Minas. At both places the *piassába* fiber is an important article of commerce. A palm draped with the fluffy mass of dark-brown fiber is a remarkable sight. The fibers are sometimes from ten to fifteen feet in length and look like very coarse hair or a tangled mass of brown twine, streaming down the trunk of the tree.

After being cut these fibers have to be dried and baled, they are then shipped to Europe and to the United States, where they are extensively used under the name of 'bast' for the manufacture of small baskets, stiff brushes, street brooms and foot-wipers. In the Amazonas valley they are used for making large cables which have the virtue of

* 'A Descriptive Catalogue of Useful Fiber Plants of the World.' By Chas. R. Dodge. Report 9, U. S. Department of Agriculture, Washington, 1897, p. 256.

floating on the water. The hard stony nut of the Bahia *piassába* is used for the manufacture of buttons.

The stiff parts of the fibers of some palms are used by the native Indians to make combs. The *tucúm* is much used along the coast in the manufacture of fishing nets and fishing lines. It is extracted by scraping away the fleshy part of the leaflet with a dull knife. The *tucúm* palms are abundant in the Amazonas valley and in the forest-

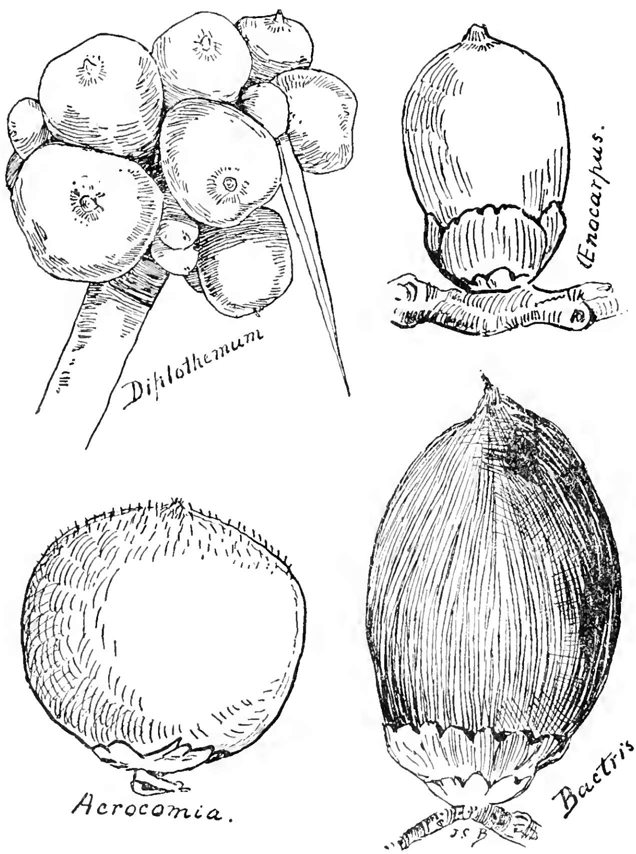

FIG. 16. EXAMPLES OF PALM NUTS; NATURAL SIZES.

covered parts of Brazil as far south as the State of Espirito Santo, and possibly further. The abundance of the plants and the remarkable strength of the fiber seem to make it possible to turn the plant to more extensive use.

Flowers.—The flowers of palm trees are very short-lived, and are therefore not available for ornamental purposes. A newly-opened spathe, however, especially of the large trees, is an impressive sight. I have never observed any marked odors about the flowers of palms, but

the swarms of bees about some of the opening spathes suggest that some of them have agreeable odors. Kerchove de Denterghem in his book on palms states that some of the flowers have very pleasant odors toward evening and morning and cites four South American genera as odoriferous.* The spathes or envelopes that enclose the flowers of certain palms are not without interest and utility to mankind. For the most part these flower sheaths are thin woody envelopes that split as the flowers open and either fall off or curl up at the bases of the fronds. They are not all so inconspicuous, however. That of the *Maximiliana regia* is so large and hard and of such a shape that it is used occasionally for baby cradles. This spathe is often four feet long by two feet wide and has a thickness of an inch or

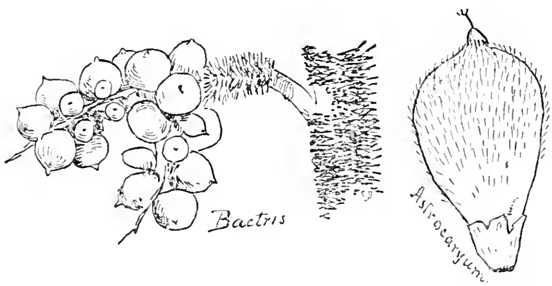

FIG. 17. PALM NUTS. THE ASTROCARYUM IS ONE FOURTH THE NATURAL SIZE; THE BACTRIS IS NATURAL SIZE.

more. The spathe of the *ubussú* is perhaps the most remarkable grown on any palm tree. It will be referred to again.

Fruits.—The fruits or nuts of the palms are usually rather small, but they range in size from that of the coco nut, which is perhaps the largest, down to the size of a small pea. Some of them have hard fibrous coatings, others are covered with a soft edible pulp; some of them are covered with short coarse hairs, some with spines, some with imbricated, reversed scales; some are fuzzy like a peach and still others are smooth like a plum; some of the clusters contain only two or three small nuts, while others form gigantic grape-like bunches larger than a single person could lift.

These fruits are extensively utilized for food both for man and for the lower animals: sometimes it is an external pulp that is eaten, sometimes it is the kernel; sometimes the pulp is used directly, often it is made into a beverage. Some of the fruits have a sweet pulp, but not a few have a pleasant subacid flavor, and several kinds are used to make vinegar.

* 'Les Palmiers; historie iconographique.' Par Oswald de Kerchove de Denterghem, Paris, 1878, p. 213.

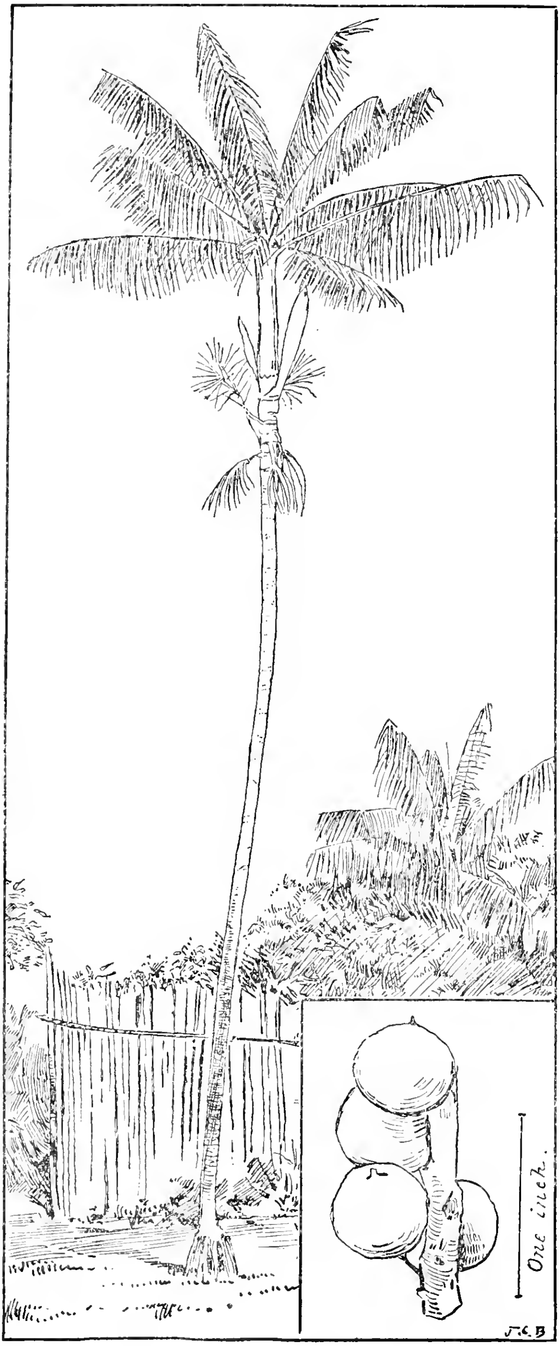

FIG. 18. THE *Assai* PALM, *Euterpe oleracea*.

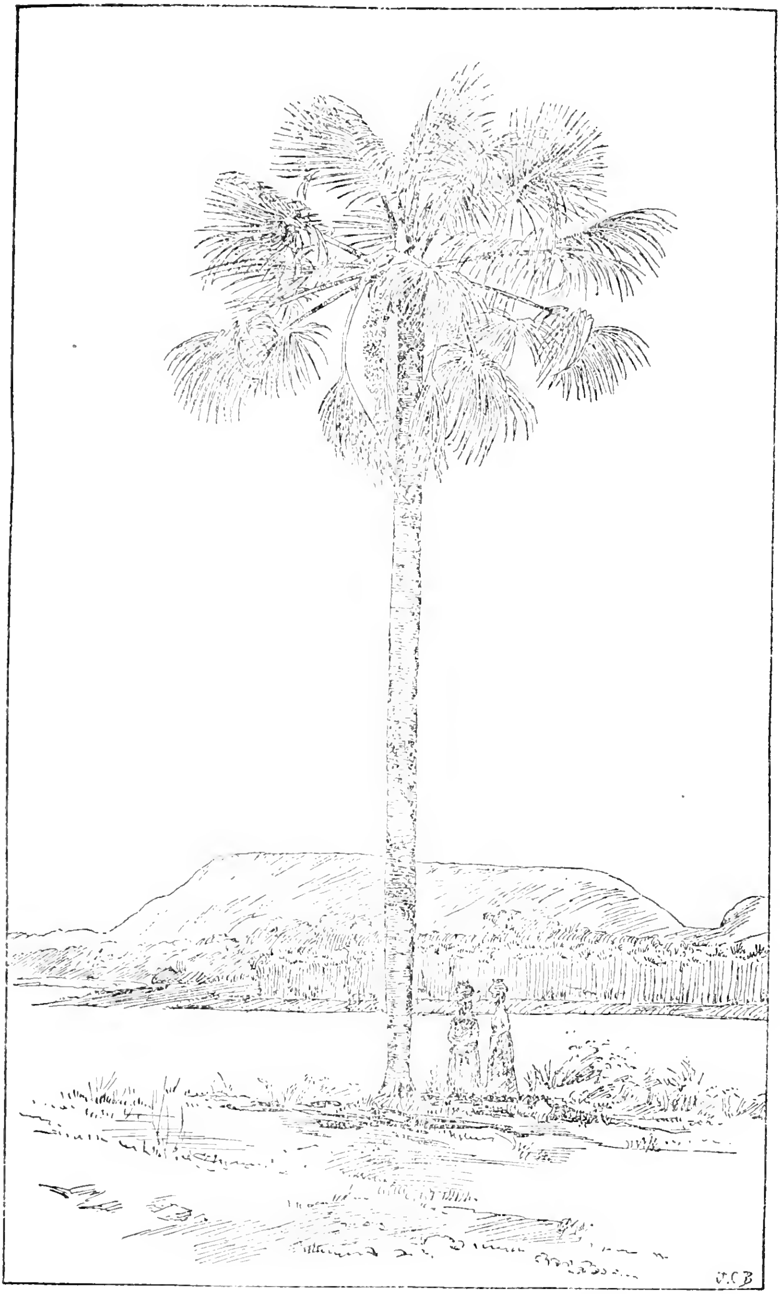

FIG. 19. THE *Mirity* PALM—*Mauritia flexuosa* OF THE AMAZONS.

The fruits of palms with which people of the temperate regions are best acquainted are dates and coco nuts. But these particular fruits are known chiefly because, besides being available as fruits, they are capable of being transported long distances and of being readily kept for a long time without danger of decay. In their native tropical countries many other palms yield valuable fruits but they do not, as a rule, admit of transportation or delay in using.

In the Amazonas valley especially, the inhabitants make a delightful beverage, known as *assaí,* from the fruit of the *assaí* palm *(Euterpe oleracea).* A stranger visiting the market in Pará for the first time is impressed by the quantities of this thick, purple, chocolate-like fluid on sale. In appearance it is rather repulsive at first, but it improves greatly upon acquaintance. From the fruit of the *baccába* palm is made a beverage very like that of the *assaí.* A similar drink, but of a milky color, is made of the fruit of the *piassába* on the upper Rio

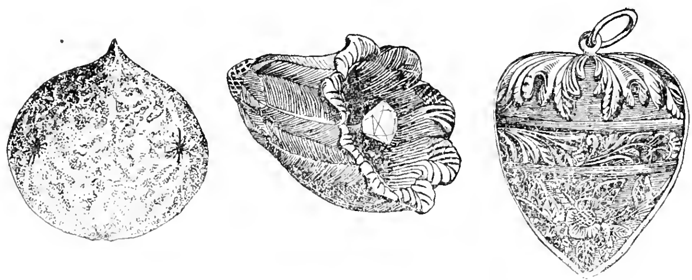

FIG. 20. THE NUT OF A PALM USED FOR JEWELRY.

Negro. A drink is make from the *mirity* * palm in quite a different manner: the tree is cut down and a hole cut in the upper side of the prostrate trunk. This opening soon fills with a nearly transparent liquid very like the milk of the coco nut. When allowed to stand and ferment this makes the *murity* wine—an intoxicating beverage. Along the coast south of Pernambuco, and especially in the State of Bahia, is a palm, known as the *dendé,* the pulp of whose fruit is used in making oil that is extensively used in cooking. This oil has a bright orange color and is prepared by bruising the pulp of the nuts, putting it in cold water and skimming off the oil as it rises to the surface, after which it is boiled down. Illuminating oil is likewise made from the kernel of the *dendé* nuts.

Many of the palm nuts are covered by edible pulp. Several species of *Bactris* bear fruits the size of a walnut whose acid pulp is very pleasant when ripe. In the Amazonas valley is a palm known as the

* This palm, the *Mauritia vinifera,* is called *mirity* and *murity* in the Amazonas region, but further south it is called *burity;* in the Paraguay valley region it is called *mburity.*

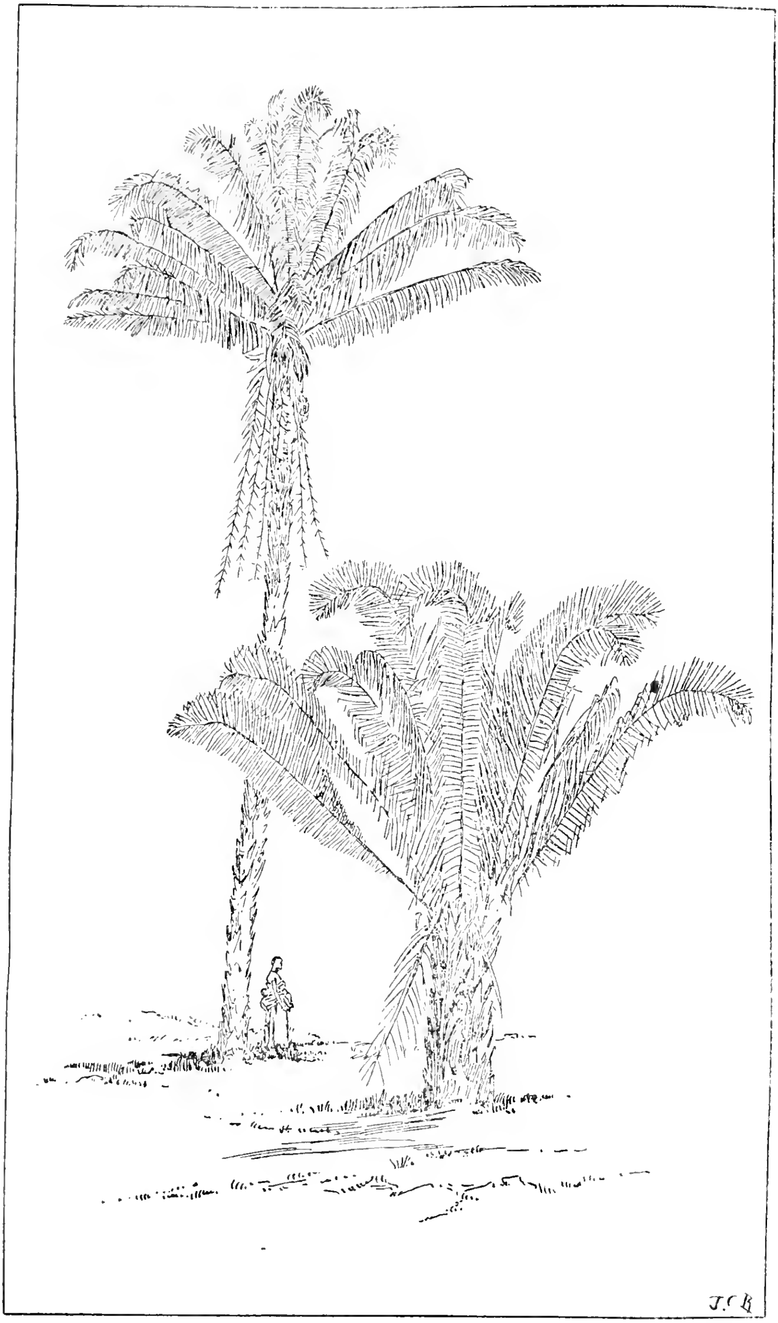

FIG. 21. THE *Urucury* (*Attalea excelsa*) WHOSE NUTS ARE USED FOR SMOKING RUBBER.

peach palm on account of its pulpy fruit. In the highlands of Brazil a small palm, a species of coco, known as the 'chifre do boi' or 'oxhorn' has a nut about the size and shape of a nutmeg. There is but little hull or flesh on the outside of it, but it is thick, black and very hard—almost impossible to crack. These pits are utilized by jewelers to make brooches, pendants and such like ornaments. For these purposes they are carved into attractive shapes, usually flower-like, mounted in gold and set with diamonds. The jewelers of Diamantina, in the State of Minas Geraes, are very skilful in the manufacture of this kind of jewelry.

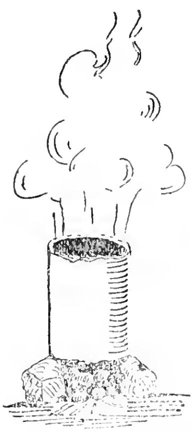

FIG. 22. NUTS OF THE *Urucury* USED FOR SMOKING RUBBER.

Urucury Nuts.—One of the most peculiar uses to which a plant fruit is put is in the preparation of rubber in the valley of the Amazonas. It is the nut of a particular species that is used for this purpose—that of the *urucury (Attalea excelsa)*.* When the milk of the rubber tree is gathered it is of the consistency of thick cream. It is prepared for the market by being dried in the smoke of a fire made of the nuts of the *urucury* palm. A flat paddle-shaped board is wet in the milk and then held over the smoke as it issues from the top of a chimney-pot-like tile a foot or so in height, resting upon stones and with the fire built beneath it. The nuts of this palm are often carried long distances for this rubber smoking.

Many of the palm nuts yield rich oils, and these are used to a greater or less extent, especially in the interior, in cooking, in the manufacture of soap and for illuminating purposes.

Special Cases.—The *carnaúba* palm (*Copernicia cerifera,* Mart.) grows naturally on the marshy uplands of northeastern Brazil, where it is put to many uses by the natives. The trunk is split for rafters, posts and fences; the leaves are used for food for cattle, for thatch, for cordage and for hats; the fruits and the growing bud are eaten; the roots are used for medicinal purposes, and from the leaves is prepared a yellowish wax that is used for candles.† The same palm is abundant through the Gran Chaco region of the Rio Paraguay, where it forms immense open forests that stretch as far as the eye can

* The nut of this palm is about the size of a man's fist, dry and without a pulpy covering, and the shell is very thick and hard. Whether there is a real virtue in the smoke of the *urucury* nuts, I do not know; the rubber gatherers insist that smoke made by other palm nuts or with wood will not answer the purpose.

† 'Notice sur le palmier carnaûba.' Par M. A. de Macedo. Paris, 1867.

reach across the vast marshy meadows. In that part of the continent it is not so extensively used,* but it is nevertheless one of the chief building timbers of that region, and its fruits are eaten by the natives, the tender phylophore is eaten as a vegetable, while the leaves are used for thatch, for fans, straw hats and cordage. This *carnaúba,* or *carandá,* as it is called in the upper Paraguay region, is one of a few social palms.

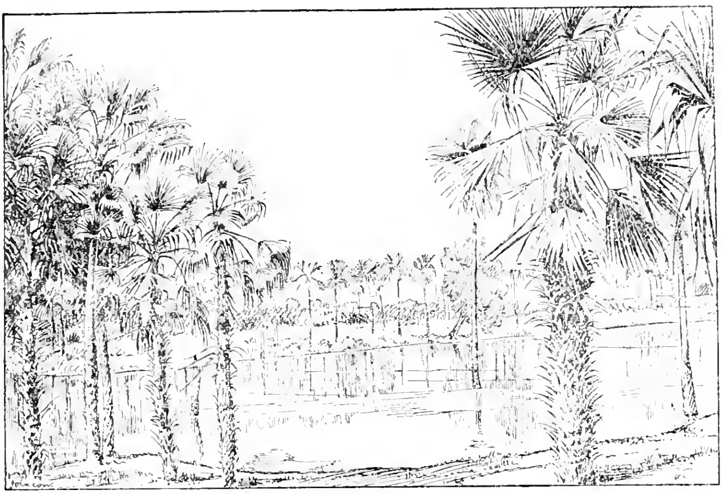

FIG. 23. *Carnaúba* PALMS ON THE PARAGUAY RIVER.

The Coco.—The coco palm (or cocoa as we erroneously call it) is not a native of South America, but it is extensively grown, especially along the sandy seashore from Caravellas, Bahia, northward. From Caravellas to the mouth of the Amazon, a distance of about two thousand miles, probably half the way the beach is flat and sandy and is actually used for growing coco palms. And it is worthy of note that these sandy beaches are of little or no value for other agricultural purposes. Almost everywhere these coco-palm groves are thickly though not conspicuously inhabited. The villages and even towns of considerable size that spring up in the groves are made up for the most part of people of the poorer classes who pass here an ideal tropical life. The posts and lath of the houses are made of the palm trunks, the roofs are made of the leaves, their food and drink are taken from the inside coco shells; the nuts are eaten green and ripe in a

* Herbert H. Smith thinks this palm different from the carnaúba of Ceará ('Do Rio de Janeiro a Cuyaba,' p. 366), but Barbosa Rodriguez, the Brazilian botanist, says they are the same ('Palmæ mattogrossenses,' p. 1). Morong reports the *Copernicia cerifera* and describes two new species from Paraguay. 'Ann. N. Y. Acad. Sci.,' VII., 245–247.

great variety of dishes, oil is made from them, the outside hulls are used for scouring and for fiber utilized in many ways, the bases of the fronds and the hulls are used for firewood, the trunks are used for skids for drawing their jangadas from the water, and the leaves are used for thatching the houses and for torches at night.

One of the Brazilian methods of using the coco nut in cooking is well worthy the attention of caterers. I refer to the use of the ripe nut in preparing codfish *à la crème*. To make this dish the codfish is prepared in the usual way, except that the juice of the coco nut is used to flavor it. The ripe nut is grated on a piece of rough tin made like a large nutmeg grater; the milk is then squeezed from the grated nut, the dry fibrous material is rejected and the white rich milk is poured in the cooking fish, furnishing both the oil and a delicious flavor for the dish.

It is somewhat remarkable that 'coprah,' the dried kernel of the coco, is not prepared in Brazil. The reason probably is that there has always been a home market for the nuts.

The young coco trees begin to bear when six or seven years old and yield fruits for more than eighty years. It is said that a coco palm yields more than two hundred nuts a year *—a statement which I feel obliged to accept with allowances.

In speaking of the foods furnished by the palm, I am reminded to mention an instance where a portion of the trunk is thus used. One palmetto is known in English as the 'cabbage palm' because the tender phylophore, or growing end of the trunk, is extensively eaten in Brazil as a vegetable, very much as cabbage is eaten. In the forests near the large cities these palmettos have been almost destroyed owing to the demand for them in the vegetable markets. I am of the opinion that many of the palms could be utilized in the same manner, and it may be that they are so used among the native aboriginal races. The using of these stems for food is open to the evident objection that once the growing bud is cut off the tree is destroyed.

The Ubussú.—One of the strangest palms in the world is what is known in the Amazonas valley as the *ubussú*, the *Manicaria saccifera* of botanists. This palm is one of a few having an entire leaf.

Every one is familiar with the fact that the leaves or fronds of palms are, in general, either palmate or pinnate. Our common Florida palms, for instance, have the fronds palmate or radiating from the outer end of a petiole; in the pinnate fronds there is a long midrib or petiole running the length of the frond and along two sides of this the leaflets are arranged.

* 'O Coqueiro da India.' Pelo Dr. J. M. da Silva Continho, Rio de Janeiro, 1889, p. 2.

FIG. 24. *Ubussú* (*Manicaria saccifera*) OF THE LOWER AMAZONS.

Now the fronds of the *ubussú* palm are not like either of these, but stand out from the trunk and behave in every way like pinnate fronds except that instead of being pinnate they are entire. The wind often whips these leaves in pieces, until they bear some resemblance to the pinnate fronds.

It is an interesting fact that those palms whose fronds are pinnate at maturity have their first fronds entire. The coco palms, for instance, have pinnate fronds, but when a young coco palm is sprouted its first leaves are entire like those of the *ubussú;* so far as I can now recall them, the same thing is true of all other palms having pinnate leaves. With the *ubussú* this embryonic character has persisted into maturity. It is this undivided leaf that is so extensively sought and used for thatching houses. Besides being entire the *ubussú* leaves are said to last for ten years as thatch.

Another interesting and peculiar character of the *ubussú* palm is its spathe or flower sheath. Some of the palms have the spathes so hard and woody that they are as stiff as if they were made of inch boards; others have them rather leathery, and after the flowers open the spathes shrivel up more or less or hang among the fruits and flowers like rolls of brown or black cardboard. The spathe of the *ubussú* is a slender, sharp-pointed and open-textured net or sack, not unlike a piece of burlap. In most palms the spathe yields but little, and when the flowers are ready to open it splits lengthwise and the flowers push out through the rent. The spathe of the *ubussú* cannot be split lengthwise; its fibers are tough and cloth-like and cross each other at low angles, and as the cluster of flowers expands the spathe stretches. In time, the fibers, on account of the great amount of moisture within, decay, and the growing flowers or fruits tear the spathe asunder, and it drops off in ragged fragments. The *ubussú* spathe is utilized to some extent by the natives of the Amazonas valley. It requires, however, to be cut before the flowers have expanded much. It is simply cut off at the stem and is drawn from over the bunch of flowers as one pulls off a close-fitting undershirt by stripping it over his head.

The cloth of this spathe is capable of a great deal of stretching if care is taken to distribute the expansion evenly. This stretching can best be done by wetting the spathe, putting the hands inside the sack and gently forcing them apart. Sacks that are not more than an inch or two across may thus be expanded to a diameter of one or two feet. One may frequently see a suit of clothes for a small boy made of one of these spathes. This is done by cutting off the pointed outer end of the spathe and cutting two holes in opposite sides near one end.

A picturesque and fairly comfortable hat can be made by pushing one end of the *ubussú* sack inside, pulling it over the head and turning

up the lower end for the rim. Hat manufacturers have occasionally utilized these spathes by pressing them into the shape of an ordinary straw hat and stiffening, binding and lining them. The chocolate-brown color and their lightness make them attractive.

The poor people of the forest regions of the lower Amazonas use this spathe also for bags and reticules, in which small articles may be tied up and hung from the roofs of their buildings. When one is in the forest and chances to need a receptacle in which to carry small articles, fruits, nuts or something of the kind, the spathe of the *ubussú* offers a homely but efficient help.

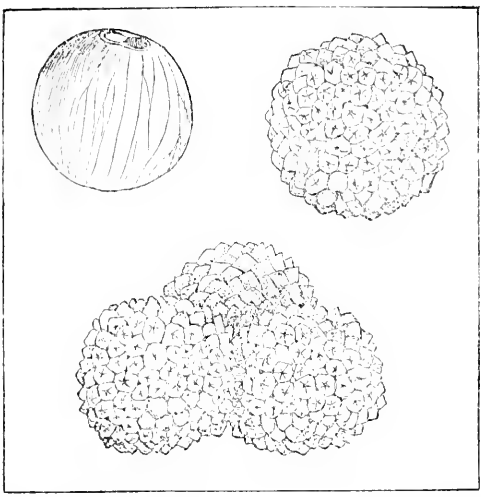

FIG. 25. NUTS OF THE *Ubussú* (*Manicaria saccifera*), REDUCED ONE HALF DIAMETER.

In general appearance the nuts of the *ubussú* palm are unlike those of any other palm; the outside coat is rough and brittle like a walnut hull, while the nut is almost as smooth as a horse-chestnut. The green nuts contain a potable milky fluid very like the milk of a green coco nut. The taste of the cut hull, however, is bitter. It is worthy of note that the nuts of this palm float in the water (most palm nuts are too heavy) and large quantities of them are swept down the Amazon and out to sea. They are said to be carried to the West India Islands (where they are known as 'sea apples' or 'sea coco-nuts'), and even to the northwest islands of Scotland.*

I have spoken here of a few of the characteristic features of a very few of the Brazilian palms, but it is not improbable that our so-called practical turn of mind may lead some of us to ask whether the palms of economic importance cannot be grown in some parts of the United

* 'Nature,' Nov. 21, 1895, LIII., 64.

States, not to speak of recent annexations. I am much disposed to think so. The U. S. Department of Agriculture has, with commendable enterprise, recently undertaken the introduction of date palms into Arizona and California,* and there can scarcely be any doubt of the ultimate success of the effort. There are many other palms that will thrive in a climate where dates can be grown.

Literature.—For the benefit of those who may wish further and more detailed information regarding palms a list of the most important works on the subject is appended; a few other titles are mentioned in the foot-notes.

1. Voyage dans l'Amérique méridionale, etc., Par Alcide D'Orbigny, Tome septième, 3e partie. Palmiers. Descriptio palmarum in Paragueria et Bolivia crescentium . . . schedulas et incones digesit. Car. Fr. Ph. De Martius, pp. 140 and atlas of colored plates. Paris et Strasbourg, 1847.

2. Historia naturalis palmarum. Auctor C. F. P. de Martius. 3 vols. folio. Leipzig, n. d.

3. Palms of British East India. By William Griffith. Calcutta, 1850, folio.

4. Palm Trees of the Amazon and their Uses. By Alfred R. Wallace. 48 plates, 129 pp., London, 1853.

5. Popular History of the Palms and their Allies. By Berthold Seeman. xvi + 359, III., London, 1856.

6. Palmæ mattogrossenses novæ vel minas cognitæ quas collegit descripsit et iconibus illustravit. J. Barbosa Rodriguez, xx + 92, 27 plates. Rio de Janeiro, 1898.

7. Palmæ novæ Paraguayenses quas descripsit et iconibus illustravit J. Barbosa Rodriguez. ix + 66, 6 plates, Rio de Janeiro, 1899.

8. Flora Brasiliensis. Fasciculus 55, Palmæ. Exposuit Oscar Drude. Lipsiæ, 1881.

9. Palmæ Amazonicæ sive enumeratio palmarum in itinere suo per regiones Americæ æquetoriales lectarum. Auctor Ricardo Spruce. Read Jan. 21, 1869. Proc. Linn. Society, XI., 65, 183.

10. New Palms collected in the Amazon valley in 1874. By James W. H. Trail. 'Journal of Botany,' Nov. and Dec., 1876, Jan., Feb. and Mar., 1877.

11. The origin and distribution of the cocoa palm. By O. F. Cook. Contributions from the U. S. Nat. Herbarium. Vol. VII., pp. 257–293. Washington, 1901.

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* 'The Date Palm and its Culture.' By Walter T. Swingle. Yearbook of the U. S. Department of Agriculture for 1900, pages 453–490. Washington, 1901.

WORK AND REST: GENIUS AND STUPIDITY.

By ALEXANDER FRANCIS CHAMBERLAIN, Ph.D.,
CLARK UNIVERSITY, WORCESTER, MASS.

OLDER far than the Tennysonian line, 'Better fifty years of Europe than a cycle of Cathay,' is the Chinese proverb, 'One day is as good as three,' *i. e.*, if you know how and when to do the thing necessary. Scott has given the warrior's version:

> One crowded hour of glorious life
> Is worth an age without a name.

Pope speaks for the statesman:

> One self-approving hour whole years outweighs
> Of stupid starers and of loud huzzas.

Through the Mohammedan saying the goddess Artemis expresses herself, 'One hour in the execution of justice is worth seventy years of prayer.' The faith of the religious votary is voiced by the Hebrew psalmist, 'A day in Thy courts is better than a thousand.' The folk and the poet, the two anticipators of science, have in all ages seen the accomplishments of great things in brief periods of intense activity. There is an aristocracy of the moment, as well as of blood or brain.

It is an interesting subject for inquiry how far the history of the individual and of the race justifies the belief that one day is as good as three, one hour outweighs whole years. In this brief paper, no exhaustive study can be entered upon, and the intention is simply to outline a theory based upon the phenomena thus recognized, and to defend the view that intense activity for comparatively brief periods alternating with longer periods of greater or less quiescence is, whatever incidents of environment, artificialities of civilization, exaggerated sex influences, etc., have at times interfered to disturb it, the normal phenomenon of work in so far as it is best and most genially productive and profitable racially and individually.

The Animal.—From the earliest times some of the lower animals have passed for models of industry, others as examples of utter sloth and idleness. But we may be sure that man has read into his observations of animal activity a good deal of his own passing reflections, for exact scientific investigation hardly justifies some of his familiar sayings. Young animals (kittens, for example) do not play so many hours of their day as is commonly supposed, and the busy bee is far

from 'improving' each 'shining hour.' The rest of young animals and children is quite as characteristic as their work or play. And we must be careful not to derive too much of our evidence from captive animals and restrained or metamorphosed children. We lack, too, authoritative delimitations of the periods of activity and of rest of animals. Groos,* in his discussion of the play of animals, has little to say on this question other than the remark: "Of children and young animals it is true that, except when they are eating, they play all day, till at night, tired out with play, they sink to sleep." But there are night-animals, and to a certain extent, night-men, for the evening activities of the kitten, *e. g.*, are often paralleled completely by those of her young mistress.

Of the lowest stages of animal life practically continuous activity has been asserted. Dr. Hodge and Dr. Aikins,* in their study of 'The Daily Life of a Protozoan,' observe: "A *Vorticella* works continuously, and shows in its life no period of inactivity or rest corresponding to periods of rest in higher animals. In other words, a *Vorticella* never sleeps." But this is only under absolutely favorable conditions of life, for the same authors, a little further on speak of a stage of rest or encystment: "Encystment is, therefore, of the nature of an enforced 'rest,' a period of inactivity imposed by exceptional external circumstances."

As we go up the scale noticeable activity and inactivity increase in their rhythmic alternations. The fishes and lower vertebrates sleep periodically, and alternate their rest and exertion. Professor McGee characterizes the intensified activity with long intervals of inertness exemplified by the Seri Indians as 'simulating the habits of carnivorous and other lower animals.' The life history of the lion and the tiger, the elephant and the camel, the horse and the buffalo, to say nothing of other and smaller animals, furnishes us with much evidence in point. The anthropoids also, though not at all studied with reference to this theory, may afford a valuable quota of proof.

With many animals hibernation, and with many others æstivation, occupies a considerable portion of their lives, the length and broken or unbroken character of the 'sleeps' or 'rests' depending to some extent upon climate, species, individuality. How far these 'sleeps' interfere with or improve the physical and mental faculties of such animals during their season of real activity is not altogether clear, but since hibernation and æstivation must at one time have been factors in the survival of the fittest, they cannot have worked entirely to the detriment of the creatures concerned, even in later days. And the same may be said of the 'winter-sleep' of the Russian peasants.

* 'The Play of Animals.' Transl. by E. Baldwin (N. Y., 1898), p. 20.

* *Amer. Journ. of Psychol.*, Vol. VI. (1895), p. 530.

The Child.—It is a fact of immemorial knowledge that the child at play, in some respects nearest the animal, in others the most typical representative of our human race, takes especial delight in continuing his activity to the uttermost extreme of exhaustion. This is true likewise of intellectual pleasures in that early age when the little child has not been subdued by the pedagogues; we see both in his first attempts to speak and to listen, and often in his imitation of his elders, the same genial exertion till weariness induces rest. Groos,* in his 'Play of Man,' discusses this feature of early childhood, pointing out, moreover, that, before the school places its ban upon the child, 'his life, apart from feeding and sleeping, is spent almost wholly in play-activities.' Play-time remains for years the absorbing, genial period of his existence. And in its acmes of intensity he exhausts himself corporeally and mentally. Some say it is 'complete absorption into the genius of the present,' others that it is 'genial repetition of self,' or 'delighted remanipulation of the right combination happily stumbled upon.' Whatever it may be, enough is revealed to make it certain that a sort of inspiration so works upon children as to make them tend to use their powers of mind and body intensely to the furthest possible limit, *i. e.*, of course, when they are moved so to do, and not interfered with by things alien to their type and mode of action. There is undoubtedly monotony in the play-intensity of childhood, but the child has not the innumerable sources of variety appealed to by the adult genius whom he so often and so much resembles. The self-imitation of the child foreshadows a similar phenomenon, broader and deeper in the adult genius, which is higher and greater than all hetero-imitation of any sort whatsoever. All things considered, these phenomena of childhood suggest that the school is on the wrong track in seeking to force upon the young lesson-restraints of several hours duration (both morning and afternoon, nay, even at night sometimes), and placing the emphasis upon a high average in all things and at all times. Ought it not rather to utilize the brief periods of intense activity fathered by heredity, perhaps, and mothered by interest? Is more than an hour really necessary for the schoolman's art to deal with the growing child? The shortening of the school-day, advocated now in divers parts of the pedagogical world, has not at all gone far enough, if it be true that a few minutes of the child at his best outweigh the mediocre rest of his hour, or even day. As the one brilliant figure or turn of speech in the arid desert of a set composition acquits the child and condemns the teacher, so the one bright answer or genial question, not the stupidity of the remainder of the lesson, should go upon record. How often the pupil is 'stung by the splendor of a sudden thought,' which the routine mind of the

* 'Die Spiele der Menschen' (Jena, 1899), pp. 472–478.

teacher fails utterly to appreciate, nay often deliberately excommunicates! The adult, as a rule, by reason of his own artificially produced 'normality,' neglects or represses those 'genial moments' of childhood, which are kith and kin with the 'inspiration' and 'intoxication' of those greatest of the race whom we recognize sooner or later as true geniuses. Another characteristic of childhood is the rapidity with which the change from play to rest, from brilliancy to apparent stupidity, from action to inaction bodily and mental can be made, and vice versa. This is particularly noticeable in American school-children, whose power of summoning up their reserve knowledge or strength (often with almost entire neglect of regular training) is remarkable. The records of the amateur dramatics, of the young people's associations of all kinds, religious as well as secular, of sports and games (here the English boy and girl count too) even, amply demonstrate this. Time and again has the instructor, driven to despair by the neglect, inattention and apparent stupidity of those in his charge, been moved to admiration by their performances when the critical moment arrived. This power of childhood, too, has been largely overlooked, or unavailed of, unappealed to, in our schools, where the desire has always been to make sure of the accomplishment of the task set by actual demonstration of the pupil's parts, rather than, by indirection, to make sure that the latent genius will, in the right setting, assert itself in a fashion unattainable by the mere artificialities of hetero-persuasion and compulsion. In this respect we have still much to learn from the philosophy of primitive peoples.

Woman.—At first blush woman would seem to be an exception to the theory outlined in these pages. The popular saying has it 'woman's work is never done,' and Professor O. T. Mason* has shown the immense amount of labor of all sorts, from the care of the tribal religion to the merest drudgery, that has been performed by her. Says Havelock Ellis:* "The tasks which demand a powerful development of muscle and bone, and the resulting capacity for intermittent spurts of energy, involving corresponding periods of rest, fall to the man; the care of the children and all the very various industries which radiate from the hearth, and which call for an expenditure of energy more continuous but at a lower tension, fall to the woman." But he admits that 'the exceptions are very numerous.' And woman has been so long under an artificial *régime* inspired by man's belief in her inferiority that many of the phenomena of work are with her no longer naïve, natural or strictly evolutional in character. The women of the Seris, *e. g.*, possess a good deal of the marked characteristics of the men in respect to intense activity, continued rest and rapid transition

* 'Woman's Share in Primitive Culture' (N. Y., 1894).

* 'Man and Woman' (London, 1894), p. 1.

from one state to the other, and the same thing may be said of other savage peoples as well. Something of this ability to change from the commonplace to the intense is seen in the quick perception and nimble action of woman's thought to-day:* "Whenever a man and a woman are found under compromising circumstances it is nearly always the woman who with ready wit audaciously retrieves the situation. Every one is acquainted with instances from life or from history of women whose quick and cunning ruses have saved lover or husband or child." The Breton fisherman confesses to a like quality in the other sex, when he replies to his questioner, 'See my wife about it,' and this is largely true of the lower and ignorant classes on the one hand, and of 'society' on the other, in most civilized communities. In this matter, as in many others, woman probably is leading the race. Traces of the night-inspiration, of the influence of the primitive fire-group, abound in woman. Indeed, it may be said (the life of southern Europe and of American society of to-day illustrates the point abundantly) that she is, in a sense, a 'night-being,' for the activity physical and mental of modern women (revealed, *e. g.*, in the dance and the nocturnal intellectualities of society) in this direction is remarkable. Perhaps we may style a good deal of her ordinary day labor as 'rest,' or the commonplaces and banalities of her existence, her evening and night life being the true genius side of her activities. It is an interesting fact that in acting and dancing, two professions essentially of the night, woman shows marked genius, exceeding even that of man. Singing may belong here also, in part at least. Havelock Ellis† finds the organic basis of women's success in acting in the fact that 'in women mental processes are usually more rapid than in men; they have also an emotional explosiveness much more marked than men possess, and more easily within call.' Again, 'women are more susceptible than men to the immediate stimulus of admiration and applause supplied by contact with an audience.' Legouvé said:‡ "It has been reserved to the female sex to produce the marvel which we admire to-day of a young girl reaching in a few months the heights of dramatic art which Talma, Lekain and Baron only attained to after long labor and in the maturity of their age." In fiction women have also scored marked success, because, as Havelock Ellis remarks: "What it demands is a quick perception of human character and social life colored by a more or less intense emotional background." These things our poets have sung to us time and again. Thus, when we consider women in the fields in which her highest genius asserts itself, we find that in general she conforms to the theory here advanced. Altogether the life of woman

* Havelock Ellis. *Op. cit.*, p. 174.

† *Op. cit.*, p. 324.

‡ Cited in Havelock Ellis's 'Man and Woman,' p. 326.

furnishes more evidence than one would be inclined at first to suspect, in support of the theory set forth in these pages. And were her individual emotional and intellectual life given more sway the evidence would probably be even greater, for, emotionally, she illustrates the theory in its most genial form, and her best-first efforts in many lines of thought and action indicate vast possibilities in the right direction.

The Genius.—Of the activities of men of genius we know altogether too little. But, as Platzhoff* has recently observed, the present is an age of personality, and there exists an intense desire to see the individual in the creative process, to catch, if possible, the personality as it metamorphoses itself into, or 'secretes,' the invention, the poem, the novel, the picture, the great thing of whatever sort. It is an epoch of biographies and autobiographies, of interviews, confessions and recollections, of diaries, love-letters, descriptions of private life, etc. At the two extremes we have an eminent *littérateur's* account of 'How I wrote my greatest novel,' and the Sunday newspaper's illustrated article on 'How Judge X. spends his vacation.' Out of this immense, incongruous mass of facts and fancies, by patient selection, it is possible to obtain some data at least of the highest importance for our view of the activity of genius. Many of the definitions and characterizations of genius have dealt with its relation to work,—'genius is mainly an affair of energy,' 'genius is nothing but labor and diligence,' 'genius is only an infinite capacity for hard work,' etc. But such characterizations of genius are born of the contemplation of the necessity under which, in our present forms of society, men of genius are compelled to work hard in order to live, and to work long in order to achieve fame. The capacity of genius for persistent, intense hard work, if it really exists, is only a temporary necessity, a transient expedient, not a permanent phenomenon of human evolution. True genius seems rather to accomplish its work by brief periods of intense activity than by unceasing labor and untiring diligence, by the *raptus,* not by the *ordo* or the *ratio.* And, apart from the necessities of the ill-regulated social system of to-day, the genius, like the child, is marked by an extreme capacity for almost 'lightning change' from productivity to infertility, from wisdom and wit to ignorance and stupidity, from activity of the intensest sort to equally noteworthy inertness. And therein he really recapitulates the race to which he belongs, for, shorn of certain excrescences acquired in the making, he is the normal man, not the abnormal, as so many critics of genius ancient and modern, will have it. Lombroso† has a brief section on the stupidity of men of genius, the noddings of the Homers of all ages, and his school has made much of

* Persönlichkeit und Werk. Zu einer Theorie der Biographie. *Arch. f. system. Philos.* (Berlin), Vol. VII. (1891), pp. 210–226.

† The Man of Genius (Lond., 1895), pp. 25–26.

such things. But, far from proving the abnormality of genius, they are one of the proofs of its general sanity and inherent humanness. The common man does not focus upon himself the glare of investigation or his 'peculiarities' would stand forth in their kinship with those of the genius who is the cynosure of all. Genius, by virtue of its humanity, has a right to be stupid here and there. Talent, which is so largely artificial, abhors stupidity, as nature is said to abhor a vacuum, or the Devil to hate holy water, but genius proves its naturalness by its occasional stupidity. The keenest eye has its blind-spot, the most highly evolved brain its non-responsive cells. Says Lombroso:* "When the moment of inspiration is over, the man of genius becomes an ordinary man, if he does not descend lower; in the same way, personal inequalities, or, according to modern terminology, double, or even contrary, personality, is one of the characters of genius. Our greatest poets, Isaac Disraeli remarked (in *Curiosities of Literature*), Shakespeare and Dryden, are those who have produced the worst lines. It was said of Tintoretto that sometimes he surpassed Tintoretto, and sometimes was inferior to Caracci."

The Criminal.—Says Havelock Ellis:† 'While he is essentially lazy . . . the criminal is capable of moments of violent activity.' The vacuous lives of criminals, with whom inertia is practically normal and continuous for long periods, have their brief epoch of excitement, explosion, diversion, uproar, intoxication, exhilaration and 'breaking out.' Indulgence in alcohol, gambling, sexual orgies, spasmodic and emotional manifestations of personality, and the like, are the sharp peaks that rise, few in number so often, from long low stretches of commonplace inertia and quiescence, or from the imprisonment that seems the normal condition of so many of them. The monotonous lapse of prison life is dotted with those outbreaks to which the German criminologists and psychiatrists have given the name of 'Zuchthausknall.' The French thief, in his jargon, calls himself '*pègre*,' or 'idler,' and a pickpocket said to Lombroso, "You see in these 'moments of inspiration' we cannot restrain ourselves; we have to steal." In the execution of many of those acts denominated crimes the offender exhibits the phenomenon of a brief period of violent activity, extreme impulsivity, great emotionality, remarkable cunning, wide-awake personality, preceded and followed by longer (often very long) periods of inertness, quiescence, impassivity, obtuseness, subdued individuality.

The Savage.—That the savage hates work has been a favorite theory with travelers and philosophers, and the etymologists, by pointing out the real significance of the terms for 'work,' which in so many languages

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* *Loc. cit.*, p. 74.

† 'The Criminal' (London, 1890), p. 143. See also pp. 144–152.

(Hebrew, Greek, Latin, Italian, French, etc.) are synonymous with pain and suffering, have corroborated such a view. Indeed, in English one word is still applicable to the 'labor' of women in child-birth, of the peasant in the field and of the man of science in his laboratory or in his study. According to Ferrero,* the habit of work is one of the great acquisitions of civilized man, who has left his opinion of its disagreeableness, not merely in words by which it is named, but also in myths and legends scattered all over the globe, in which the necessity to labor is represented (as in some of the Eden stories) as a result of the sinfulness of the fathers of the race. Vierkandt,† in his recent study of savagery and civilization, synthetizes these two stages of human progress as 'play' and 'organization' respectively. Professor Karl Bücher,‡ of Leipzig, who devotes one section of a very interesting and suggestive book to the 'work methods of primitive peoples,' reviews briefly the 'horror laboris' theory, pointing out that the latest and most trustworthy studies of savage and barbarous peoples indicate, beyond a doubt, that a very large amount of work is performed by them, though the impulses leading up to it are not the same as those which influence the work of cultured races, the technical aids are very imperfect, the work processes complicated, and a tendency to artistic elaboration and adornment is marked among the uncivilized peoples. With Ferrero, Bücher holds that the *horror laboris* could hardly have originated from bodily fatigue, since many of the phenomena of activity among primitive peoples, notably some of their dances, continue until utter weariness and exhaustion end them. According to Bücher,§ it is aversion to effort of the mind and will, not repugnance to bodily exertion and fatigue, that causes the savage to dislike work. His dislike is of psychic origin, and in such performances as the dance, which are carried on to the point of exhaustion and fatigue he finds 'an easy means of discharging, without destroying the condition of mental inertia so characteristic of him, the accumulation of nerve-force in his intellectual organs.' That this theory can be carried too far and that the dance and cognate activities are not the only ones which the savage is capable of carrying on in genius-fashion is evident from the researches of Boas and other competent and thoroughgoing students of primitive man. The most suggestive of all recent writings on this head is Dr. W J McGee's‖ account of the Seri Indians of Tiburon Island and the adjacent Sonoran coast of the Gulf of California. These Indians are not

* 'Les formes primitives du travail.' *Rev. Scientif.* (Paris), 1896, pp. 331–335. See also: Les lois psychologiques du symbolisme (Paris, 1895), pp. 13, 24.

† 'Naturvölker und Kulturvölker' (Leipzig, 1896).

‡ 'Arbeit und Rhythmus.' 2te Aufl. (Leipzig, 1899), pp. 1–23.

§ '*Loc. cit.*, p. 21.

‖ Seventeenth Ann. Rep. Bur. Amer. Ethnol. (Washington, 1898 [1901], pp. 1–128, 129*–344*.

merely 'one of the most strongly marked and distinctive of aboriginal tribes,' but 'must be assigned to the initial place in the scale of development represented by the American aborigines, and hence to the lowest recognized phase of savagery.' In Dr. McGee's detailed description of this remarkable tribe of savages, the following passage is significant:

"So the observer of the Seri is impressed by the intensity of functioning along lines defined by their characteristic traits, and equally by the capriciousness of the functioning and the remarkably wide range between activity and inactivity which render them aggregations of extremes,—the Seri are at once the swiftest and the laziest, the strongest and the most inert, the most warlike and the most docile of tribesmen; and their transitions from rôle to rôle are singularly capricious and sudden. At the same time the observer is impressed by the relatively long intervals between the periods of activity; true, the intense activity may cover hours, as in the chase of a deer, or days, as in a distant predatory raid, or perhaps even weeks, when the tribe is on the warpath; yet all the known facts indicate that far the greater portion of the time of warriors, women, and children is spent in idle lounging about rancherias and camps, in lolling and slumbering in the sun by day and in huddling under the scanty shelter of jacales or shrubbery by night,—*i. e.*, when their activity is measured by hours, their intervals of repose must be measured by days."*

This is an entirely different view from that which travelers of a day have expressed concerning savage and barbarous man, and statements such as those of Rengger about the pathological slowness and stupidity of the Guarani, as Hirn† terms it, must be read in a new light. And perhaps we may say the same thing about Sproat's‡ characterization of the Indians of Vancouver Island, which has been cited with approval by Spencer. Many travelers and investigators have seen the savage during the period of laziness and stupidity only and have ascribed to him these qualities alone. But while the Seri Indians are so well developed somatically, are runners in a land of running peoples (their very name signifies 'spry'), are expert paddlers in very stormy waters, excellent hunters and warriors of high prestige, in fact possess a physical strength-reserve which makes them masters of their habitat, 'they have been no less notorious among the Caucasian settlers of two generations for unparalleled laziness, for a lethargic sloth beyond that of sluggish ox or somnolent swine, which was an irritating marvel to the patient padres of the eighteenth century, and is to-day a by-word in the even-tempered land of Mañana.' Moreover this inactivity is so complete that 'the sinewy hands and muscular jaws are noticeably inert during the intervals between intense functionings, are practically free from the spontaneous or nervous movements of habitually busy persons, and con-

* *Loc. cit.*, p. 156.

† 'The Origins of Art' (London, 1900).

‡ See: F. Boas in *Proc. Amer. Assoc. Adv. Sci.*, 1894. Here Sproat's error is pointed out.

tribute by their immobility to the air of indolence or languor which so impressed padres and rancheros.' Just as complete is the transition from the manifestations of race-hatred culminating on the war-path to 'the abject docility of the Seri when at peace and in camp.' Altogether the Seris offer a brilliant example of intuitive relying upon reserve strength to the disregarding of the mechanical and artificial devices known to civilization, which so often make the individual absolutely dependent upon them and not upon himself, causing many a dire calamity in times of real storm and stress. The rapidity of the transition from extreme inertness to extreme activity is also emphasized by Dr. McGee. It therefore seems that the long periods of inactivity do not appreciably injure either the brief periods of activity or inhibit the swift passage from one to the other so characteristic of these savages. According to Dr. McGee the Seri have acquired a 'race-sense' in these matters, that never fails them.

Generalizations are always hazardous, but we can hardly doubt that the Seris as described by Dr. McGee more fairly typify the savage and primitive man than do certain other tribes glimpsed at by incompetent or casual observers.

The Race.—That the races of man, and perhaps all mankind considered as a whole, have their alternations of activity and inactivity is very probable. Particularly is this true when we consider some special quality, which may be said to correspond to genius in the individual. There are 'lean' and 'fat' years of racial genius. Havelock Ellis, in his careful study of 'British Genius,'* notes as one of the two most important factors, 'a spontaneous rhythmical rise and fall in the production of genius'; this is indicated in the distribution of men of genius by centuries and half-centuries, etc. The so-called 'ages' of English history—Elizabethan, Victorian—the Augustan period in Rome, the era of Pericles in Greece, and their innumerable counterparts in the annals of other lands afford proof of the rhythmic movement of racial genius at its best in comparatively brief intervals, while the 'dark ages' of much longer duration are represented in many other parts of the world than in Europe. The renaissances and revolutions of various sorts, the outbursts of political energy, invention, maritime discovery, literature, dramatic art, etc., represented in Athens by the period 530–430 B. C., in England by 1550–1650 A. D., and in America by 1783–1814, are well worth studying from this point of view. For Europe the brief period 1550–1700 is particularly glorious, since during it there came into the world Spenser, Marlowe, Shakespeare, Bacon and Lope da Vega, while during the period 1620–1640 were born Dryden, Locke, Molière, Racine and Spinoza. Italian art, Semitic religion, Greek philosophy, Hindu metaphysics and Chinese rationalism are not with-

* Popular Science Monthly, Vol. LVIII., p. 379.

out a like periodicity. Throughout European history especially there can be traced waves of activity and inactivity traversing every avenue of human thought and expression. For the race, as well as for the individual, the '*magnum opus*' is performed in the '*minimum tempus*,' —a year is often more than a century.

We have now considered in the life of the animal, the child, the woman, the genius, the criminal, the savage, the race, the theory that brief periods of work at the highest possible tension alternating with longer periods of rest or changed activity represent the best working conditions and have found not a little evidence to support it in every quarter. The experience of other than mere professional athletes, the methods of animal trainers, the results of half-time schools, the progressive reduction of the hours of labor for working-men and shop-employees will furnish many more data of the same kind. It has been argued that two hours physical labor *per diem* would suffice, were the product economically distributed, to keep the whole world well supplied, so great has been the advance in labor-saving machinery, methods of transportation, etc. Is it altogether unreasonable to suppose that two hours intellectual work, under right conditions and with economic distribution of the product, would suffice to keep the whole world supplied here also? Two hours of every one's best would be something worth achieving, physically and intellectually. An end something like this is the ideal to which things are bound to tend. Some poet of the future may be able to sing: 'Better the New World hour than the long European day.' The racial nervousness of the American people, non-pathological in reality, is perhaps the groundwork for this achievement.

SCIENCE IN 1901.*

IN a review of the scientific work of 1901, astronomy, as the oldest of the sciences, may fitly claim first mention, especially as it fell to the astronomers to make what was, on the whole, the most exciting discovery of the year. This was a new and brilliant star in Perseus, which appeared to spring into existence in a remarkably sudden manner. That portion of the heavens in which it was situated was photographed at Harvard on February 19, and no sign of it was to be detected on the plates when they were developed; yet only a day or two afterwards it was seen by Dr. T. D. Anderson, of Edinburgh, and by other observers as a star of between the second and third magnitude. The suddenness of its appearance was equalled by the rapidity with which its size varied, and this inconstancy, together with the extraordinary changes that took place in the character of its spectrum, provided astronomers with a theme for speculation, the resources of which are yet very far from being exhausted. In April a new comet, said to be the brightest since that of 1882, was discovered in the southern hemisphere by several observers. In May its tail, which at first was 10° in length and curved slightly to the south, split into three parts. On May 18th, there was an eclipse of the sun, the line of totality passing across the Indian Ocean through Sumatra, Borneo and New Guinea. The party from Greenwich selected their station in Mauritius, where the duration of totality was only three and a half minutes, and enjoyed the advantage of good weather. Other observers who took up their positions in Sumatra had a longer (six minutes') duration of totality, but were not quite so fortunate as regards weather.

In pure physics, perhaps the most interesting single achievement of the year was the experimental proof that light, as predicted by Maxwell and by Bartoli, exerts a mechanical pressure. Many observers have already attempted to detect this phenomenon, among them being Sir William Crookes, who at first thought he had succeeded in so doing with his radiometer, until it was found that his effect was many thousand times too great. Curiously enough, success was announced almost simultaneously in two different quarters, by Professor Lebedew, of Moscow University, in Europe, and by Messrs. Nicholls and Hull in America. The work of the latter observers appears to be the less precise of the two, for they do not claim that it does more than prove the existence of a pressure, not due to gas-molecules, of the nature and order of mag-

* From the London *Times*.

nitude required. Professor Lebedew's measurements are, however, in close agreement with the amounts as calculated from the theory; he finds that the pressure per square meter is 0.4 milligram for absolutely black bodies, and double as much for perfect reflectors. This experimental verification of one consequence of Maxwell's wonderful electro-magnetic theory suggests reference to another which is gradually passing out of the experimental stage and becoming of practical utility. It is only a few years since Principal Lodge astonished the British Association by showing that the electric waves in connection with which Hertz's name is famous, could be propagated to a distance of half a mile or so; yet already the wireless telegraphy so initiated has become a recognized portion of the equipment of ships in all the important navies of the world. In the mercantile marine, too, it is making way, so much so that Lloyd's, in the course of the year, contracted to have it fitted in a number of their signal stations round the British coasts. Almost every country can show workers who are engaged, with more or less success, in perfecting its appliances, among them being Popoff in Russia, Slaby in Germany, Guarini in Belgium, Ducretet in France, and Marconi in England. The last-named, by using waves a thousand feet long, succeeded in detecting electro-magnetic radiation which had traveled, 1,800 miles from the source that produced it, and he is looking forward to the early establishment of a commercial system of sending messages across the Atlantic by wireless telegraphy, and later to opening up communication with the Cape. But while the performance of such feats in long-distance transmission is certainly a legitimate object of ambition, it must not be forgotten that very much remains to be done in perfecting wireless telegraphy for comparatively short distances. If ever it is to become of real commercial importance, means must be found not only to enable two parties to communicate with each other without fear of their message being overheard, but also to prevent a third party from making communication impossible altogether by the simple device of working his own apparatus and thus rendering the signals unintelligible. Even before these refinements comes the necessity of ensuring certain transmission of simple signals over moderate distances. The imperfections of present methods are sufficiently illustrated by the experiences of the *Ophir* and her consorts, and by the difficulty which the Admiralty have found in obtaining coherers that can be trusted to respond satisfactorily over their test-distance of 70 miles —a difficulty which has induced them to take the manufacture of these delicate pieces of apparatus virtually into their own hands.

Of all the physical forces which it is the business of science to investigate, none bulked more largely in the public eye than electricity. The idea of distributing current for various purposes from a central station to a large surrounding area made distinct progress during the year,

though in Mond gas Parliament sanctioned a novel and rival method of power transmission. While its use for lighting, for electrolytic manufactures, etc., steadily advanced, it was in regard to its applications to traction that electricity was most conspicuous. Some schemes of this sort were brought into actual operation, some were definitely decided upon; but more still were mere suggestions, few of which have much chance of being translated into fact. Among the last class must be ranked the host of tube-railways which threaten to invade London. If Parliament were to sanction all those proposed and if (what is not less unlikely) their promoters were to obtain the money for their construction, it seems that in some places the subsoil of the City of London would be transformed into a solid mass of iron tubes, and it is doubtful whether there would even be room for all in the earth, whatever the ingenuity of drawing-offices may do in plans. This activity on the part of promoters is largely a result of the success of the Central London Railway, but it is conveniently forgotten that there are other tube railways which cannot point to anything like similar results. In the near future, too, it does not seem improbable that there may be a change in popular sentiment in favor of shallow lines just below the surface, where efficient ventilation will be obtainable; for people are discovering that steam and sulphur are not the only things that make an atmosphere offensive, and they may soon realize that to roll a mass of used-up air forwards and backwards in a narrow tunnel, without ever renewing it, does not constitute ventilation sufficient either for comfort or for health. During the year many towns brought electric traction into operation on their surface tramlines, and after protracted obstruction the authorities of Kew Observatory, who feared that certain magnetic observations carried on at that somewhat unsuitable site would be injuriously affected by stray electric currents, agreed to withdraw their opposition to the opening of the first electric tramway seen in London, in consideration of the company which owns the lines contributing £10,000 towards the expenses of moving the instruments. Among proposals which were definitely determined upon may be mentioned the adoption of electrical propulsion for the Mersey Railway in Liverpool, and for the Metropolitan and District Railways in London, both to a large extent with the aid of American capital. For the latter, two systems were considered—the Ganz polyphase and the ordinary direct current. The question which should be selected was referred to the Board of Trade for decision, and as soon as that step was taken the matter was practically settled, for few could doubt but that so eminently conservative a body would choose a system which has been well tried in various parts of the world, in preference to one which has scarcely passed the experimental stage, and which, moreover, involves the employment of electricity at a much higher pressure than it is used to. In another case also the

Board was made master of the situation, for Parliament, while passing the Bill for the Behr Monorail high-speed line between Liverpool and Manchester, practically delegated the power to authorize the construction of the line to that body, which must approve of the engineering details before work can be begun, and may require the promoters to carry out any preliminary experiments it thinks necessary. From the point of view of public safety there are doubtless advantages in this policy of entrusting everything to the Board of Trade, but its practical effect will probably be that British engineers will be debarred from taking the lead in any new electrical development which conceivably involves risk to human life. In connection with high-speed lines, mention must be made of the experiments carried out in Germany on the Berlin-Zossen military line, where, by the aid of electricity at a high voltage, a speed of about 100 miles an hour was obtained, not, it would appear, without some damage to the permanent way.

That wide field of inquiry which lies in the borderland between physics and chemistry is attracting an ever-increasing number of workers. Though no discovery of outstanding importance was made, the Cambridge school can point to a year of solid work on the phenomena of ionization and the existence of bodies many times smaller than molecules, and, in spite of the protests of some chemists, the ionic dissociation hypothesis continues to find increasing favor among the great body of physicists. In France progress was made in the investigation of the radio-active bodies by M. and Mme. Curie, Becquerel, and others; the first-named inquirers made the observation that the rays emitted by radium exercise a burning and eroding effect on the skin. In Germany, Bredig and Ikeda continued their remarkable experiments with 'inorganic ferments,' in particular following out the analogy between the catalytic action of colloidal platinum and that of organic ferments in regard to the action of poisons. They find that the rate of decomposition of hydrogen peroxide in presence of colloidal platinum is influenced to an extraordinary degree by substances like prussic acid, hydrogen sulphide, and mercuric chloride, even in minute quantities. Thus the catalytic effect of a platinum solution is halved by prussic acid, even when the concentration of the latter is only 0.0014 milligram per liter; the effect of this substance is, however, only temporary, and the solution gradually recovers in course of time. A large number of substances exert this poisoning action to a greater or less extent, but there are some which intensify the catalytic action of the colloidal platinum, among them being formic acid and dilute nitric acid. Experiments have also been tried with a colloidal solution of gold obtained in a manner similar to that employed in the case of platinum, by passing an electric current between gold wires in a dilute solution of sodium hydroxide. This gold solution, which is bluish-violet in color

and contains one gram atom of gold in 1,360 liters, on the whole resembles colloidal platinum in its action, but it is remarkable that the same agents are not poisonous to both. Thus mercuric chloride, one of the strongest poisons for colloidal platinum, exerts an opposite influence on the catalyzing power of colloidal gold in alkaline solution.

Professor Gamgee's investigations into the magnetic qualities of the blood again touch physics on the one hand and physiology on the other. Starting from Faraday's observation that blood is a diamagnetic fluid in spite of the iron contained in its coloring matters, he has found that, while oxy-hæmoglobin is powerfully diamagnetic, the hæmatin and hæmin which may be obtained from it by the action of certain acids are strongly magnetic. He is extending his inquiries to the products obtained by the electrolysis of oxy-hæmoglobin. Mr. H. Swithinbank has been carrying out an elaborate investigation into the effects produced on tubercle bacillus by exposure to the cold of liquid air. He finds that prolonged exposure to that temperature, and even actual soaking in liquid air, has little or no effect on the vitality of the bacillus, though its virulence is to some extent modified. Length of exposure, indeed, does not seem to be an important factor, but what does produce a decided destructive effect on the vitality and virulence is exposure to alternations of temperature, as when the bacillus is frozen in liquid air, allowed to warm up to normal temperature, cooled again, and so on. The most striking incident at the Tuberculosis Congress held in London in July was the pronouncement by Professor Koch that bovine and human tuberculosis are distinct diseases, and that consumption is not transmissible from cattle to human beings. His views by no means commanded universal assent, and it was generally felt that more evidence was required before they could be accepted, and especially before any relaxation could be seriously contemplated in the sanitary regulations which have been framed on the assumption that the disease is so transmissible. During the proceedings of the Congress great stress was laid on the value of the open-air treatment of consumption, and as a result a strong impetus was given to the movement for establishing sanatoria where it can be carried out. One important semi-public institution of the kind was brought into use near Wokingham in the course of the year, and the erection of several others in various parts of the country has been determined upon. A sum of £200,000 placed at the disposal of the King by Sir Ernest Cassel has also been devoted by His Majesty to the erection of one of these sanatoria. Another mode of treating consumption, which did not receive nearly so much attention at the Congress, has been tried by Dr. Maguire, of the Brompton Consumption Hospital, with very promising results. This consists of the intravenous injection of formalin in carefully-graduated strengths and amounts. The effect, even in some very advanced cases, has been a rapid

lowering of the temperature, and even after the immediate action of the injection has passed off the patient experiences relief from the *malaise* which is so distressing a consequence of high temperature. The drug appears to possess in particular a controlling influence on streptococcic and staphylococcic infection, and it seems probable that its use may be extended to the treatment of other diseases.

Increased light is being thrown on mosquitoes as agents in the propagation of disease. Not only has more detailed information been gained as to the part they play in the causation of malaria, preventive measures based on that information being put in operation with a certain amount of success, but evidence has been brought forward which indicates that the spread of yellow fever also is due to them. That disease, at least, has developed in persons who have been bitten by mosquitoes, while others protected from mosquitoes have escaped, even though they courted infection, according to older ideas, by wearing clothes and sleeping in bedding which had been used by yellow fever patients. In Glasgow there was an outbreak of smallpox in the early part of the year, and plague appeared in one of the large hotels; but, owing to the vigorous measures adopted, neither disease succeeded in gaining any stronghold. In London, too, smallpox is prevalent to a greater extent than it has been for a considerable period, though there can scarcely be said to be an epidemic in the sense in which that term was used twenty or thirty years ago.

In natural history the most interesting discovery was that of a new mammal in the Congo *Hinterland.* Sir Harry Johnston obtained from the Semliki Forest a complete skin and two skulls, and a reconstruction of the animal may now be seen in the Natural History Museum at South Kensington. At first it was thought to be of a zebra-like character, on the evidence of certain stripes on its skin, but further investigation dispelled that notion, and Professor Ray Lankester has diagnosed it as a giraffine animal. It has been named *Okapi Johnstoni.*

The men of science who died during the year include three who took high rank among physicists—Professor Tait, of Edinburgh, Professor Fitzgerald, of Dublin and Professor Rowland, of Baltimore. The first-named had reached the age of three score and ten, but the other two were both comparatively young men from whom much good work, in addition to what they had already achieved, might confidently have been expected had they lived. Both education and science were the poorer by the death of Principal Viriamu Jones, of University College, Cardiff, in succession to whom another physicist has been appointed in the person of Mr. E. H. Griffiths. On the other hand, two veterans of science—Virchow in Germany and Berthelot in France—celebrated the completion of fifty years of scientific work.

FRANKLIN'S PHILOSOPHICAL SOCIETY.

BY DR. ELLIS PAXSON OBERHOLZER,

PHILADELPHIA, PA.

MR. FREDERICK FRALEY, who died in Philadelphia on September 23, at the age of 98 years, was the president of the oldest learned society in this country, the American Philosophical Society. He occupied this office longer than any other president except Benjamin Franklin. Both Mr. Fraley and Dr. Franklin served for twenty-one years, Franklin the first president, from 1769 until 1790, and Fraley the last, from 1880 until 1901. Thomas Jefferson was president of the Society for eighteen years, or from 1797 to 1815, therefore during the entire time he was president of the United States. David Rittenhouse served it in this capacity from 1791 until his death, and some facts in the life of an organization which boasts of such early connections should be recalled by a generation to whom its history is very little known.

Behind the State House in Philadelphia, where the Declaration of Independence was adopted and liberty was proclaimed throughout the land, where the Continental Congress met, where the Constitution of the United States was framed and the American government was established, where the new Congress convened for ten years and Washington, Jefferson, Adams, Hamilton, Morris and the fathers of the Republic were figures passing through its doors and down its corridors, as familiar as the old porters and watchmen who now guard the relics that are displayed there to the populace, stands a detached colonial building of red brick which is almost as old as Independence Hall itself. This is the Hall of the American Philosophical Society, and it so closely abuts upon one wing of the State House that it seems to be almost a part of it. Its rooms downstairs are hired out to-day to stockbrokers, but the apartments in the two upper stories are hung with interesting portraits and filled with busts and books and relics of another day, a trust bequeathed to the living members by a notable galaxy of men who created the Society to propagate scientific knowledge in the new world.

Nearly everything of any antiquity in Philadelphia may be traced back to Benjamin Franklin. It was he, of course, who founded the American Philosophical Society. When a young man still at work at the printing trade he organized a number of his fellows into a club which he called the Junto. This band of young Philadelphians met

at the homes of the members and in the city taverns to discuss scientific or 'philosophical' questions—what becomes of all the water that flows into the Mediterranean Sea, whether 'elementary fire' and the electric fluid were the same thing and other ponderous problems calculated to engage the interest of the rising generation in the eighteenth century.

It was in 1743 that Franklin, then a man of thirty-seven with several successes to his credit, announced to his friends his plans for a larger Junto. It was to be a national society 'for promoting useful knowledge among the British Plantations in America.' It was to have a president, a secretary and a treasurer who should live in Philadelphia, since this city was assumed to be more centrally located than any other in America. In Philadelphia, too, there should be always resident seven members, a physician, a botanist, a mathematician, a chemist, a mechanician, a geographer and a general natural philosopher. Into these various departments it was conceived at the time that all learning or philosophy could be brought, and Franklin proffered his own services as the Society's secretary. The body was to receive members from every part of the colonies, and they were 'to maintain constant correspondence' with each other, to the end that whatever useful information one might secure might be passed on to the others and in this way be made the common property of the people.

The founders, however, seemed not to be able to make the Society thrive. The colonies still contained too few who were interested in the propagation of useful knowledge and after a brief period of activity the members were obliged to suspend their meetings. It was not until 1767 that there were signs of awakening life, when many men of prominence in Philadelphia and its neighborhood were elected to membership. In the meantime, a rival society had become quite active, and negotiations for union were begun. A basis of agreement having been reached, in January, 1769, the two societies officially christened 'the American Philosophical Society held at Philadelphia for promoting useful knowledge,' the cumbrous title which the body still retains, met together for the first time. Dr. Franklin was made the president of the consolidated societies, while he was still absent in England; and thus, twenty-six years after he had originated the idea, a period that had been full of progress and change for him, as well as for the American colonies, he lived to see his early hopes realized in a scientific society whose fame was soon to spread over the whole civilized world.

Although abroad almost constantly he remained president of the American philosophers until his death. He occupied the chair for the first time in 1775, but returned to Europe almost immediately to be absent for another period of nine years. Wherever he wandered, however, he was always mindful of his obligations to the Society which each year reelected him to its chief office. His personal triumphs as

the American Ambassador at the court of France were all grist to the mill of the Society which gained corresponding members from the *literati* of Europe and exchanged its transactions with every principal scientific body in the world. Membership in a short time came to be looked upon as a mark of distinction for most of our revolutionary leaders, for Washington and the other presidents of the United States, for the Supreme Court judges, the members of the cabinet, senators and congressmen and for the various diplomatic representatives who made Philadelphia their headquarters while the city was the American capital.

Strange ideas haunted the minds of the philosophers, and scientists in Europe must have chuckled with amusement when they read some of the Society's reports. Franklin's practical spirit breathes through this statement of the purposes of the Society, which was published in the first volume of the Transactions in 1771:

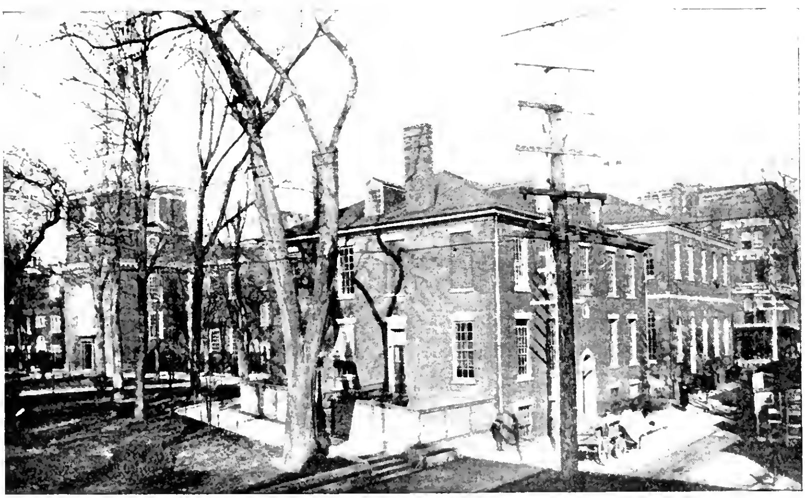
> Knowledge is of little use when confined to mere speculation. But when speculative truths are reduced to practice, when theories grounded upon experiments are applied to the common purposes of life; and when by these agriculture is improved, trade enlarged, the arts of living made more easy and comfortable and of course the increase and happiness of mankind promoted, knowledge then becomes really useful. That this Society therefore may in some degree answer the ends of its institution the members propose to confine their disquisitions principally to such subjects as tend to the improvement of their country and the advancement of its interest and prosperity.

The writer of this salutatory fondly hoped that America would in time come to possess much likeness in the wealth of its industries to China. It lay in the same latitude as China and our climate was like the Chinese climate. "Could we be so fortunate," said the American Philosophical Society, "as to introduce the industry of the Chinese, their arts of living and improvements in husbandry, as well as their native plants, America might in time become as populous as China which is allowed to contain more inhabitants than any other country of the same extent in the world." To England no less than to her colonies the philanthropic work of the Society should make appeal, 'for if by these means the continental colonies can supply her with the rarities of China and her islands can furnish the rich spices of the East Indies her merchants will no longer be obliged in order to obtain these to traverse three quarters of the globe, encounter the difficulties of so tedious a voyage and after all submit to the insolence and exorbitant demands of foreigners.'

The trees in the wood and the bushes by the roadside were full of possibilities for these philosophers so young in scientific investigation. The persimmon and the sassafras trees, the sumach, the leaves of which the Indians mixed with their tobacco, 'to render it more aromatic and agreeable in smoking,' and many trees and plants it was surmised might yield mankind drugs and dyes and other useful products. Great store

was laid by the experience of the Indians and many of their secrets the philosophers hoped to gather from them for the common benefit of man.

The hopes of many protectionists of a later time who have labored strenuously to encourage the development of native industries were anticipated by the Philosophical Society. Its members early had a care for the silkworm and the mulberry tree. Franklin sounded the note in a letter written in 1770, and the venerable Peter S. Duponceau, long the president of the society, a distinguished lawyer and philologist who in his youth came hither from France to serve Baron von Steuben as his private secretary during the Revolutionary war, carried on extensive experiments in silkworm culture at his own expense. The Pennsylvania Assembly was asked to pass a bill establishing a public filature in Philadelphia. Eggs were to be distributed and bounties paid for a term of years to the most successful producers of the cocoon.

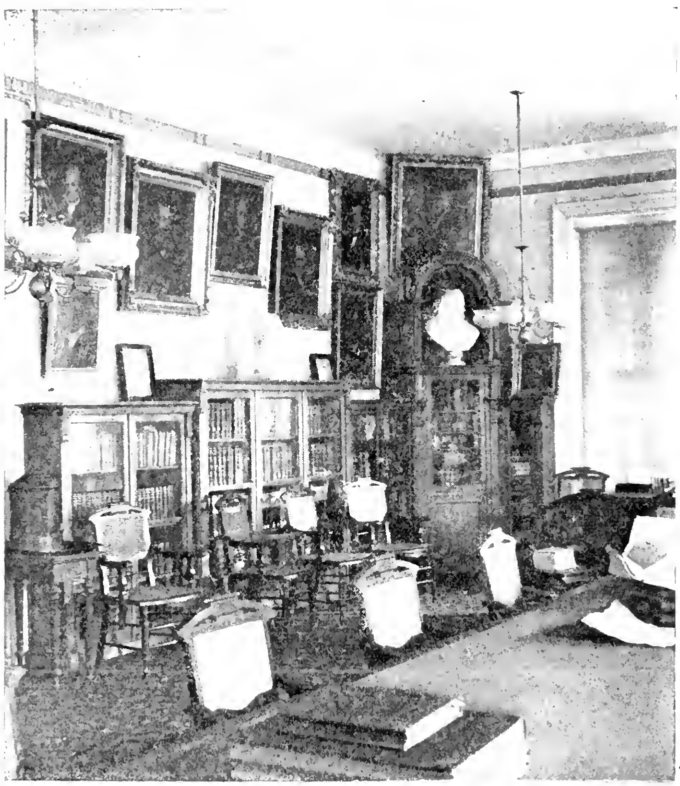


BUILDING OF THE AMERICAN PHILOSOPHICAL SOCIETY.

While the philosophers were not able to convince the legislature that public duty lay in this direction, a private association to encourage silkworm propagation was afterward organized under the auspices of the Society and it received £1,000 from the Pennsylvania Assembly in furtherance of its ends.

The wine grape also greatly appealed to the interest of the Society, which made a collection of receipts for the manufacture of wine forwarded to it by farmers and other colonists who had had experience of the vine in America. The uncleared land was well covered with wild vines, and it was assumed that by a little experimentation the colonies could be made to yield wine fruit abundantly.

In 1791 Dr. Rush thought he saw in the maple the future source of the world's sugar supply. This benevolent man hoped that the growth of the tree might be generally extended. "I cannot help contemplating a sugar maple tree with a species of affection and even veneration," said the great advocate of emancipation, "for I have persuaded myself to behold in it the happy means of rendering the commerce and slavery of our African brethren in the sugar islands as unnecessary as it has always been inhuman and unjust."



PLACE OF MEETING IN THE BUILDING OF THE SOCIETY.

Accounts of many interesting things crowd the early records of the Society. Franklin himself while coming home from France on his last tedious voyage diverted himself in calm weather by writing his famous letter 'on the causes and cure of smoky chimneys,' which he tells us are chimneys that instead of 'carrying up all the smoke discharge a part of it into the room, offending the eyes and damaging the furniture.' He also describes a new stove for burning pit coal, while Thomas Jefferson's interest in husbandry is evidenced by his

model of 'a hand threshing machine,' invented by a Virginian, and his communication in regard to a new plowshare.

Natural history had many enthusiastic students. America was a great boneyard which before the fertilizer companies despatched their agents everywhere afforded much that was of curious concern to naturalists. Skeletons of strange animals, tusks, antlers and 'grinders' came pouring into the Society's museum. Jefferson described 'certain bones of a quadruped of the clawed kind' found in western Virginia. Another member put into print an Indian legend about 'the big naked bear.' Without offering any of its bones in evidence, he tells us that the bear, naked all over except for a spot of white hair upon its back, was the most ferocious of American animals. It devoured man and beast and was so large that an Indian or a common bear served it for but a single meal. Its heart was so small that the arrow could seldom find it. It could be slain only by a blow deftly dealt upon its backbone, and many who went forth to hunt this terror of the forest primeval never came back again.

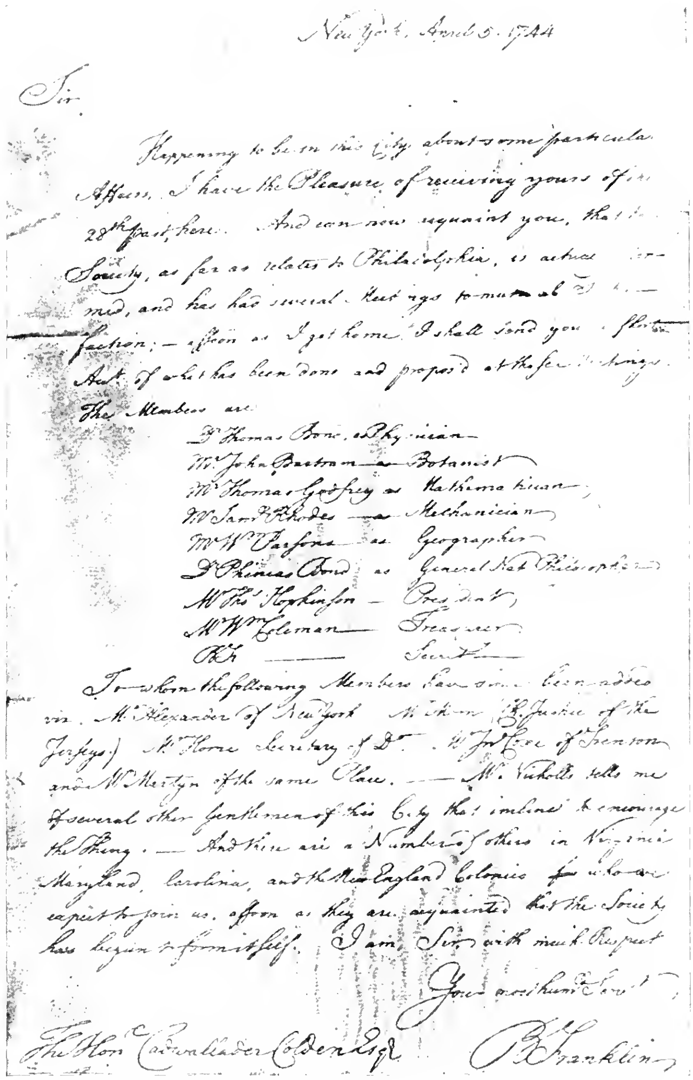
Other philosophers interested themselves in living objects and we have luminous accounts of 'amphibious serpents,' 'one partridge with two hearts,' 'the numb-fish or torporific eel' and 'a living snake in a living horse's eye.' This horse had been placed on exhibition in Philadelphia by a free negro, who undertook to profit by the popular curiosity for disagreeable sights.

The Society early engaged itself in a scientific work which brought it wide recognition, and quite deservedly so. Already in 1768 Professor Ewing made a report to the philosophers in regard to an impending transit of Venus which it had been calculated would occur in the summer of the following year. Before that time the phenomenon had been observed only twice and then rather partially, the first time in 1639 and again in 1761. A reflecting telescope was imported from England through Franklin's kindly intercession. The day when it arrived proved to be perfectly clear, and the observations were so well made and were recorded in so scientific a manner that the Society at once gained a high reputation among men whose good opinion it was worth while to possess. An eminent authority in Europe at that time wrote of this achievement:

> The first approximately accurate results in the measurement of the spheres were given to the world not by the schooled and salaried astronomers who watched from the magnificent royal observatories of Europe, but by unpaid amateurs and devotees to science in the youthful province of Pennsylvania.

Almost simultaneously with this manifestation of the seriousness of its mind came a proposal from the Society to undertake the surveys for a canal which should be cut to join the Chesapeake and Delaware bays. To make possible this laudable work the philosophers asked the

merchants of Philadelphia to subscribe to a fund. They responded very liberally, and the Society at one time had as many as fifteen persons in its service taking levels and making surveys upon the various routes.



New York, April 5. 1744

Sir.

Happening to be in this City about some particular Affairs, I have the Pleasure of receiving yours of the 28th past, here. And can now acquaint you, that the Society, as far as relates to Philadelphia, is actually form'd, and has had several Meetings to mutual Satisfaction; — As soon as I get home, I shall send you a short Acct. of what has been done and propos'd at these Meetings.

The Members are

Dr Thomas Bond, as Physician
Mr John Bartram as Botanist
Mr Thomas Godfrey as Mathematician
Mr Saml Rhodes as Mechanician
Mr Wm Parsons as Geographer
Dr Phineas Bond as General Nat. Philosopher
Mr Thos Hopkinson — President
Mr Wm Coleman — Treasurer
B F — Secretary

To whom the following Members have since been added viz. Mr Alexander of New York Mr Morris (Ch. Justice of the Jerseys) Mr Home Secretary of Do. Mr Jno Coxe of Trenton and Mr Martyn of the same Place. — Mr Nicholls tells me of several other Gentlemen of this City that incline to encourage the Thing. — And there are a Number of others in Virginia, Maryland, Carolina, and the New England Colonies, who we expect to join us, as soon as they are acquainted that the Society has begun to form itself. I am, Sir, with much Respect

Your most humble Servt

The Honble Cadwallader Colden Esqr. B Franklin

AUTOBIOGRAPHICAL LETTER OF BENJAMIN FRANKLIN ON THE ORGANIZATION OF THE AMERICAN PHILOSOPHICAL SOCIETY.

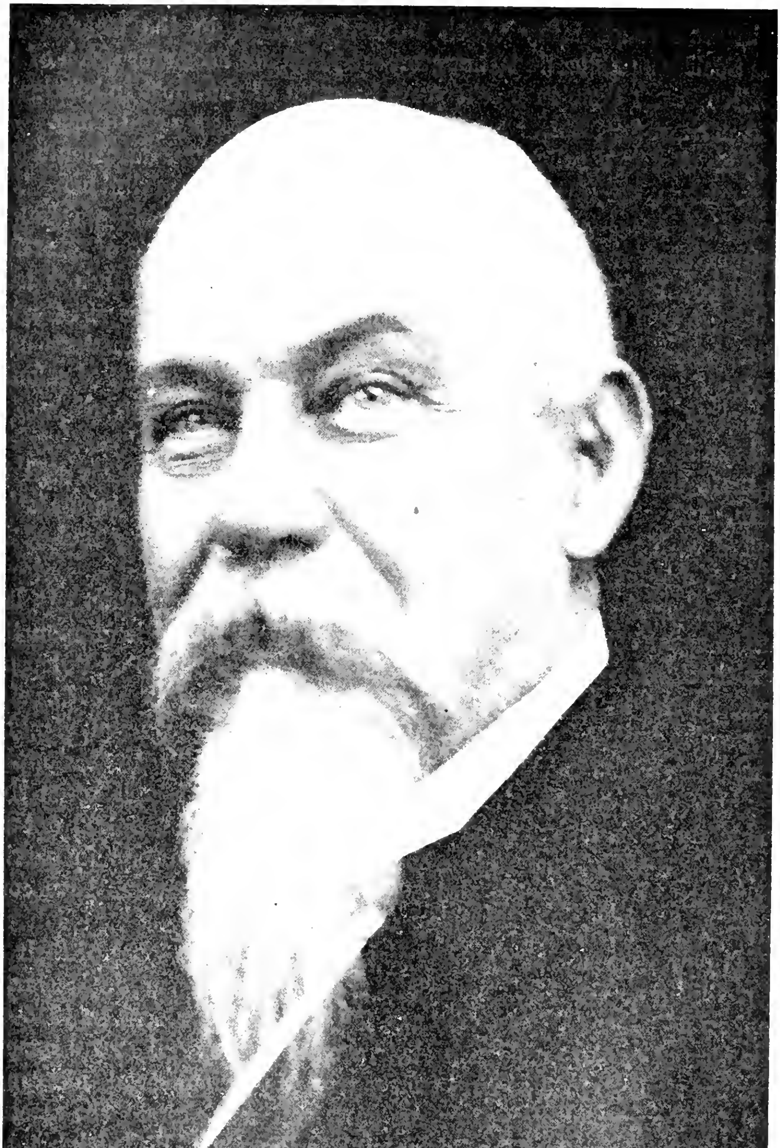
When the philosophy of the eighteenth century was at last broken up into parts and was followed by the special sciences, the Society suffered intellectually of course. It has not been able to make a choice

of bent. In the 158 years of its existence it has published about 65 volumes of proceedings which attest to the catholicity of its interest. Divergencies of mind in the nature of the case must prevent that sympathy and congeniality which formerly existed in the membership. The Society's publications, however, are reference books for much of the excellent work done in recent years by some of the most indefatigable of American scientists, such as Leidy, Brinton, Lesley and Cope.

The Society's collections include many old prints, documents and manuscripts, the library being particularly rich in Frankliniana. The rooms are hung with oil portraits of the Society's presidents and of distinguished members. Sully's Jefferson, Peale's copy of Martin's Franklin, Peale's Rittenhouse, Stuart's Washington, Sully's Wistar and Rush and busts of Franklin, Lafayette, Condorcet, Turgot, Cuvier, Rittenhouse, Provost Smith and many other eminent members of a former day are to be seen in this little treasure house, so full of colonial memories. Most of the specimens of natural history, the old models and the like have been distributed among the museums where they can be more freely used by students. But the principal trophies still remain, such as Franklin's chair, a curious leather-covered construction stuffed with hair in which he used to sit when the Society met at his home in his last days.

Another chair in the hall is the famous Jefferson chair. It is a quaint squat chair with an arm as broad as a table and it is upon this arm that Jefferson is said to have written the Declaration of Independence, an original autograph draft of which reposes in the Society's fireproof. The chair turns round by means of some awkward, clanking machinery which exists inside it, and it is a curiosity worth stopping to view. One of the high Rittenhouse clocks which still keeps time inside its old pine case, the theodolite with which Penn laid out the city of Philadelphia, an old cell battery used by Franklin in making his electrical experiments and other interesting apparatus have come down to the Philosophical Society from a hoary past.

It now aims to invigorate its members with a new sense of their responsibilities. On Mr. Fraley's death General Isaac J. Wistar, a nephew of Caspar Wistar, who was the Society's president in 1815–18, was elected to the president's chair, and it is proposed that a general meeting shall be held at least once a year to promote social intercourse and for the presentation of papers on scientific subjects. The meeting this year has been fixed for Easter week in the city of Philadelphia, and arrangements are in progress for the reception and entertainment of the members who are expected to gather there from all parts of the country on that interesting occasion.



ALPHEUS HYATT.

ALPHEUS HYATT.

BY PROFESSOR W. H. DALL.

IN the death of Professor Alpheus Hyatt, of Cambridge, philosophical zoology in America has sustained a loss only second to that which was involved in the death of Cope.

Alpheus Hyatt was born in the city of Washington, District of Columbia, April 5, 1838. He was a scion of an old and honored Maryland family; from whom the suburban village of Hyattsville, near Washington, took its name; and which is still well represented in Baltimore. He lost his father early but his mother survived to a venerable age, dying in Washington hardly more than a year before her son.

Young Hyatt was a pupil of the Maryland Military Academy, subsequently entering the class of 1860 at Yale, but after the Freshman year he left the college for a year's travel in Europe. In 1858 he went to Harvard as a student of Louis Agassiz, in the Museum of Comparative Zoology, entering the Lawrence Scientific School from which he finally graduated in 1862. During the war of the Rebellion he served in the Forty-seventh Massachusetts volunteer regiment and left the army with the rank of captain, subsequently taking up post-graduate studies in Germany. In 1867 he married Miss Andella Beebe, of Valatia, New York, and became a curator in the celebrated Essex Institute of Salem, Mass., in which so many of the naturalists and historical writers of the last half century found at one time or another a congenial environment. About that time a particularly large group of workers was located in or about Salem, and in connection with Morse, Packard and Putnam, all ex-pupils of Agassiz, Hyatt took part in founding the Peabody Academy of Sciences in Salem. These four naturalists for some years formed its scientific staff, and by them, with the help of Scudder and others, the *American Naturalist* was started on its career of usefulness.

In 1870 Hyatt was elected custodian and, in 1881, curator, of the Boston Society of Natural History, at the same time, and for some years subsequently, serving as professor of zoology and paleontology at the Massachusetts Institute of Technology in Boston. He also had charge, up to the time of his death, of the important collection of invertebrate fossils in the Museum of Comparative Zoology, and was one of the collaborators of the United States Geological Survey in its field work and paleontological researches.

Not content with personal devotion to research, Hyatt always felt it a duty to communicate as far as possible to other students and teachers the knowledge he had gained, which might render them capable not only of doing better educational work, but of themselves entering the ranks of the little army of investigators. This led him to make cruises in a small vessel with a crew of selected students, even as far east as the maritime provinces of Canada, and to the establishment at Annisquam of a summer laboratory for the study of marine life by teachers and students of zoology. This has now been superseded by more extensive and subsidized summer schools, called for by the great increase of interest in such studies, but, for some years, with no official support or collegiate subvention, Annisquam led the way. Similarly, aided by an association of friends of science, largely inspired by himself, Hyatt was instrumental in starting the Teacher's School of Science at the rooms of the Boston Society of Natural History, contributing by supervision, lectures and the preparation of science primers a great part of the elements of its success.

Hyatt was one of the originators and the first President of the American Society of Naturalists, an association of professional workers in zoology and botany which meets annually for exchange of ideas and methods and the promotion of acquaintance and good-will among its members. His labors for the promotion of science and for thorough research were universally appreciated among his fellow-workers, though not of the sort which leads to personal advertisement or miscellaneous popularity. Scientific men everywhere recognized his merit. He was elected a member of the American Academy of Arts and Sciences at Boston in 1869. In 1875 he became a member of the National Academy of Sciences. Brown University in 1898 gave him the degree of LL.D. and he was a correspondent of many foreign learned societies.

In the line of research Hyatt devoted his attention chiefly to invertebrate animals. Among his early papers was a contribution to the report on an expedition in which Verrill and others joined for the exploration of the Island of Anticosti, which, wrapped in fogs and beaten by tempestuous surges, had been almost untrodden by scientific men. Hyatt reported on certain remarkable fossils of the paleozoic rocks of the island. A memoir on some fresh-water polyzoa, illustrated by exquisite drawings and characterized by thoroughness and finish on its scientific side, attracted much attention. A paper on the evolutionary progress, illustrated by the Tertiary forms of *Planorbis* at Steinheim, as they occur in successive lake beds at that well-known German locality, pointed to the principles to the elucidation of which a large part of his scientific career was devoted. A memoir on the commercial sponges of North America received high encomiums from foreign naturalists as a model treatise on a particularly difficult subject. A very suggestive

contribution to philosophical ontogeny was his 'Theory of Cellular tissues' which appeared in 1885. The group upon which most of his labor was spent and in the discussion of which he was recognized as *facile princeps,* is that of the tetrabranchiate cephalopods, popularly known as ammonites, which in early geological ages attained such a marvelous development. More than in many other mollusks the organization of the ammonite is reflected in the characters of the shell and the infancy, maturity and decline of the group to which it belongs is, to the qualified student, pictured in the characteristics of the successive portions of the lustrous coil of the fossil shell. By removing successive portions of these involving symmetrical whorls, the characters of the animal, from the larval stages to senile decay, may be unfolded. Hyatt's researches among these animals set the pace for the most eminent students of the group throughout the scientific world, and his most important publications were devoted to them. With an audience of perhaps a dozen living men who were fully qualified to appreciate the minutiæ of his studies, it was not likely that their value could be popularly estimated. But the principles worked out were of far-reaching importance for the students of evolution everywhere, and will bear fruit in the future. A series of similar evolutionary studies of the land shells of the Hawaiian Islands was nearly completed at the time of his death.

Hyatt's studies of evolution, in geologic time, as well as on existing animals, led him to what are sometimes called Neo-Lamarckian conclusions. He believed in the hereditary transmission of acquired characters, and, in one case at least, proved their transmission. In common with Cope and the majority of American zoologists who have not derived their prepossessions from exotic teachers, he pursued the ideas of Lamarck and Darwin to their logical conclusion, as revealed in the genetic history of the animals he studied, and added to them a body of evolutionary philosophy with which all schools will have to reckon.

Leaving a subject which verges on the present conflict of scientific theories, it remains to say a few words, all too inadequate, on the man whom we have lost. No one who had the privilege of Hyatt's acquaintance but will join in testimony to his high-minded scientific integrity; the infectiousness of his hearty enthusiasm; the fertility of his imagination, which yet was always controlled by constant reference to experience and observation; and the general atmosphere of good fellowship which he diffused. Unpretentious, open-minded, a constant example of clean living, high thinking, and unassuming kindness to all about him, an ideal husband and father, a steadfast friend; we shall not soon look upon his like again.

Professor Hyatt leaves a widow, a son and two daughters, whom the sympathy of his colaborers in two hemispheres may in some slight degree sustain under the consciousness of their common loss.

SUICIDAL FANATICISM IN RUSSIA.

By Professor W. G. SUMNER,
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IN 1897 reports ran through the newspapers of the civilized world that a religious sect in southern Russia had begun to practise suicide from religious motives. In June of that year Mr. I. A. Sigorski, professor of psychiatry and nerve diseases in the university at Kieff, visited the scene of the transactions in order to make a psychological investigation of them. The following account is derived from his book.*

The scene was in the rich valley of the Dniester, in a cluster of farmsteads near the village of Ternova, three or three and a half English miles from Tiraspol. The family of Kovaleff and its connections owned several of these farmsteads. The one at which the events occurred was a valuable estate which belonged to a family of that name who were Old Believers (Raskolniks=schismatics). On the estate was a building which presented, on the outside, the appearance of a carriage shed with large doors. In fact there was no opening at all on that side. On the inside a pile of straw and reeds masked the entire exterior of the building and joined the roof, so that it looked like a solid store of those commodities, but behind this pile was a corridor which gave entrance to the building. There was another corridor inside by which connection was established with the main residence. This building was a refuge and more or less permanent residence for Old Believers of both sexes when on a journey, or old, or ill or persecuted. The name of it is a 'skeet.' It had been so used for a century, and the construction shows that the inmates lived in gloom and secrecy, apprehending danger and violence, and prepared to flee through the concealed passages in one direction or the other. They went out only by night, or singly, and as secretly as possible. Their favorite occupations were prayer, reading the books of their sect and religious conversation. In these observances the Kovaleff family joined with great interest.

In the autumn of 1896, for some reason which is not definitely known, the inmates of the skeet were thrown into excitement. Relics

* 'The Epidemic of Voluntary Death and Suicide in the Farmsteads of Ternova'; republished from the journal 'Problems of Nervo-Psychic Medicine.' Kieff, 1897. 99 pp. (In Russ.)

of a Russian saint having been found, the whole state church underwent a revival of religious enthusiasm, in which the schismatics did not share, and which they had nothing to offset. One explanation of the later proceedings is that there was a desire to create a 'holy place' for the Old Believers. The head of the estate at that time was Madame Kovaleff, and the head of the skeet was a woman named Vitalia. The former was an elderly lady, in easy circumstances, simple-minded and benevolent. The latter was 35 or 40 years old, energetic, decided, fanatical, narrow-minded and bigoted. She led and ruled the whole establishment. She practised austerities (or pretended to), read religious books, and interpreted what little she heard of the outside world by the absurdly ignorant and wrong-headed notions of the sect. These facts about her account for her influence. She and one or two of her intimates began to talk of persecution, war, enforced military service and the end of the world. The Old Believers were to be exiled or imprisoned. It was agreed, in this community, that, if they were imprisoned, they would starve themselves. Then, however, a new cause of anxiety arose; what would become of their children? They thought that these would be forcibly baptized in the state church, and such a consequence filled them with dismay.

After Christmas there were rumors that a new national census was to be taken with registration for military service. Vitalia declared that war was imminent, that Anti-Christ was about to appear. Registration was the seal of Anti-Christ and damnation. It would be far better to die at once by voluntary starvation and so escape all these terrors and persecutions. A girl of thirteen years, acting no doubt on suggestion from Vitalia, first spoke of voluntary interment. She said: 'In prison they will torture and kill us. It would be better to bury ourselves.' Her mother replied: 'Your idea is good. I agree with you.' The only able-bodied man who could dig a large hole was Theodore Kovaleff, son of the Madame Kovaleff above mentioned. His wife took up the idea of voluntary burial. Referring to the fear that children, if left behind, would be educated in the state church, she pressed her babe to her breast and said: 'I cannot give him up to damnation. I would rather go into the burial pit with him.' Vitalia warmly approved this sentiment. Theodore opposed the project, but his mother favored it, partly on his account, lest he should lose his faith under torture in prison. Vitalia taught that as many drops as there are in the rain so many years of torture are there in hell for the unfaithful, but the faithful would suffer only two or three days in the burial-pit, and then enter into the Kingdom of Heaven.

There was some scruple about suicide in the minds of some members of the group. Voluntary death they considered different. The

traditions of the sect for two hundred years contain tales of self-immolation by burning, drowning, burying, sometimes by hundreds at once, as forms of voluntary death, to escape from persecution or the coercion of the state whose laws they resisted. When the census agents came to the door of the skeet a document in archaic form and language was handed out as the sole reply. It read as follows: "We are Christians. We are not allowed to adopt any new things, and we cannot consent to register our names and places of abode over and over again. Christ takes the place to us of all things; therefore of name and country. Your new institution and your census list would alienate us from Christ, and from true Christian faith, and would lead us to the renunciation of our fatherland, for our fatherland is Christ. Our Lord speaks to us by his Holy Gospel. Our Lord says to His disciples: 'Every one who confesses me before men will I confess before my Father in Heaven, but every one who denies me before men will I deny before my Father in Heaven.' Therefore we answer you briefly but decidedly that we will not deny our Lord Jesus Christ, and that we are not willing to forsake the orthodox faith, or the Holy Synods, or the Apostolic Church. What the Holy Fathers accepted in the Holy Synods that we also accept, but what the Holy Fathers and the Holy Apostles rejected and anathematized that we also reject and anathematize. We can never consent to sin as we should by obeying your new laws. We prefer to die for Christ."

The first interment took place in the night of December 23, in a cellar or subterranean vault adjoining the farmhouse of one member of the sect. A 'mine' was dug to connect it with the cellar of the building. The vault was about 13 feet square and 5½ feet high in the middle. After religious services, those who were to be buried put on the grave clothes of the sect. Nine persons entered the vault, a man of 45, his wife of 40, his daughter aged 13, the wife of Theodore Kovaleff, aged 22, and her two children, one aged three years, the other an infant, a woman of 35, and an old man of 70. The first named man inside and Theodore Kovaleff outside closed the entrance with earth and stones. The buried persons had with them candles, sacred books and sacred image-pictures.

The second burial was made on the night of December 27. About a mile from the place of the first burial there was an excavation which had been made for a house. At one corner of this a horizontal 'bottle-shaped' hole was made by Theodore. Six were entombed here, of whom three were children, seven, four and two years old. One man and his wife disagreed about joining the party. He took their two-year-old daughter and went in. His wife became a mother again immediately afterwards. Another man in this party was a disreputable and

abandoned drunkard and loafer. He was led to enter by the will of his mother and sister, not by his own. It appears almost certain that the second party did not know of the interment of the first party. Vitalia enforced strict secrecy.

On the 5th of February Vitalia and six others were arrested on a formal charge of not having passports, in connection with their refusal to comply with the census and registration. When imprisoned they all refused to eat or drink. They refused all gifts of food, saying that their religion required them to earn their subsistence entirely by the labor of their own hands. They persisted in this course for four days, and it appears that they would have committed suicide in this way, but

THEODORE KOVALEFF.

they were released and put under house arrest with police supervision.

Some rumor of the interments got out and the excitement in the sect grew more intense, being mixed with doubt and some uncertainty as to the right of what had been done. On the night of February 12 the third party was buried. It consisted of four women who entreated Theodore to dig the grave for them. He did so and lifted his sister down into it, she being too weak from the recent prison starvation to descend into it. This was a large grave. The women lay close together at the bottom. Theodore threw the earth first on their feet, then on

their bodies, and at last on their heads, and trampled it down. He stated afterwards that he heard no sound from them during the operation.

The misgivings at what had been done affected Madame Kovaleff and Vitalia differently. The former was sad and doubtful, and felt the responsibility. The latter felt that she must die, and she wanted to die with glory. She was anxious to persuade Madame Kovaleff to die with her. She feared all forms of death except the slow death of starvation. She set the fourth and last act of interment to include

THEODORE KOVALEFF.

herself, for February 21st. The refusal of one old man in the skeet caused a postponement until the 28th. At that time the estate was surrounded by water on account of the spring rise of the Dniester. The police guard left, taking the boats with them, since the people could not escape. An opportunity was thus offered for the fourth interment. Theodore and his half-witted brother, Dimitri, dug a kind of niche in the cellar wall of the house in which the first interment took place. It was 4½ feet long, 8 feet wide, and not over 2 feet high. Madame Kovaleff, her son Dimitri, Vitalia, and two of the latter's most intimate confidants crept into this space, bending their heads and drawing up their feet. Theodore replaced the cellar wall. All were in great terror and confusion of mind. The total number who met death was 25.

Great interest attaches to Theodore Kovaleff. He was the most responsible person in the whole party. He never assented to or believed in any of the ideas and plans. He was the agent of the whole transaction. By his hands his wife, children, sister, mother and brother died. He did what he was told to do. Vitalia's final orders to him were not to eat or drink, but to await the end of the world which would come in a day or two. He held out four days; then as there was no war, as no one came to take him to prison, and the world did not end, he began to eat. When the facts became known and he was questioned, he said that they did not think they could go wrong in obeying Vitalia, because she fasted, prayed, read good books, etc., and he repeated the question: 'Why was there no one to set us right?' His portraits, which are here reproduced, show that he is a stupid and ignorant but harmless peasant. The face portrait shows an expression of anxiety and distress, as of a man who finds himself in a situation which he can not understand. In the full-length picture which represents him in the costume of a monk of the Old Believers, his face shows more of the mild melancholy which, as Sigorski tells us, was one of the traits of his character.

The reports of the existence of a sect, one of whose religious principles is suicide, prove to be unfounded. The religious element in the affair was small and remote. The Old Believers have fallen into an attitude towards society and the state which is traditional and false, although not without some historical explanation and excuse. They are under the dominion of fixed ideas and live in a seclusion and ignorance which cause them to take a false position towards all their surroundings. They fear imaginary enemies and unreal dangers. Their extreme ignorance of the world causes them to adopt crazy projects for meeting enemies and dangers. All this nourishes fanaticism and bigotry up to the stage of insanity. Then there are traditions of the extravagant behavior of their ancestors in the sect to suggest for imitation models of right and noble action. When a man is at hand of feeble character and stupid submissiveness to act as the agent of the half-insane fanatics all the elements and conditions of the tragedy are provided.

THE DIFFERENTIATION OF THE HUMAN SPECIES.

BY PROFESSOR LINDLEY M. KEASBEY,
BRYN MAWR COLLEGE

ZOOLOGICALLY considered, the human race constitutes a single species which has in the course of time become subdivided into a number of ethnic varieties. Scientifically speaking, this differentiation of the human species into ethnic stocks is an instance of organic variation, and, as such, subject to biological interpretation. Applying the general principles of organic evolution to the particular case, ethnic differentiation may, accordingly, be regarded as the result of environmental agencies operating through the process of selection upon the attribute of variability inherent in the anthropoid line.

Recent paleontological evidence renders it reasonably certain that mankind was homogeneous before the ice-age, and that heterogeneity entered in during the glacial period. It may be taken for granted, therefore, that the first stages of ethnic differentiation were established by the great geographic changes that occurred at this time. As the ice-sheets advanced successively from the arctic and antarctic regions and the thermal equator oscillated at long intervals about the geographical equator, the climate of the northern and southern hemispheres alternated between equable and frigid conditions, and the surface of the earth was modified accordingly. Thus so long as the ice-age lasted, the human race was subjected to the influences of a varying environment. Upon the final retreat of the glaciers, the configuration of the earth gradually assumed its historic form and the globe became divided as at present into temperature zones. After this, time introduced no further changes in the general geographic conditions, but place peculiarities became permanently established and regions of the earth differed from each other in climate and topography. So instead of the human race being affected as before by a varying environment, varied environments henceforth influenced different portions of mankind. The effect of these varying and varied environments was first to alter, and then to diversify, the conditions of human survival. This necessitated adaptation on man's part, which in turn led to the differentiation of the human species; so that by the close of the glacial period heterogeneity was established where homogeneity had previously prevailed.

Owing to the numerous instances of migration and miscegenation that have occurred since the ice-age, the ramifications of race are now-

adays extremely complex. Looking from above downward, it is consequently difficult to define the lines of ethnic division with any accuracy. The analytical method furnishes sufficient distinctions, however, to establish a general classification of humanity. Taking the shape of the skull, the texture of the hair, the pigment of the skin and general structural characters into account, ethnographers have concluded that there are four elementary divisions of mankind, known particularly as the Negro or Black race, the Mongolic or Yellow race, the Caucasic or White race and the American or Red race.

Looking from below upward, it is out of the question, of course, to follow the lines of racial ramification chronologically. But though the time factor fails for the most part, the place element can usually be determined with considerable accuracy. Ethnic consequents can, accordingly, be connected in each instance with their geographic antecedents, and the outcome of the interaction between variability and environment set forth in some detail. Thus though it is out of the question to establish the chronological sequence exactly, by supplementing the analytical with the geographical method of enquiry, it should at least be possible to indicate the general order of racial ramification and determine under what environmental conditions the ethnic differentiation of mankind took place.

Corresponding to the fourfold ethnic division of the human race, there are four more or less distinctly defined geographic sections of the globe. Three of these racial regions radiate from Indo-Malaysia, the cradle-land of mankind; the fourth is situated on the opposite side of the earth, though connected in the far north with the continental area of the eastern hemisphere. Considering the situation somewhat more in detail, the four habitats may be defined as follows: Toward the south, the Indo-Malaysian abode borders upon what we may call the 'eastern-equatorial section,' which stretches out between the tropics from the west coast of Africa, across the partially submerged Indo-African continent, to Melanesia and Australia. This intertropical belt has from time immemorial been the abode of the Negro or Black race. North of the Indo-Malaysian cradle-land lies the vast 'Asiatic section' of the eastern hemisphere, which is separated from the southern peninsulas by the Himalayan line, except along the Pacific coast where passage to the north is possible between the longitudinal ranges of Cochin-China. This continental area is the traditional abode of the Mongols or Yellow people. Between the equatorial belt and the Asiatic area, the 'Indo-Mediterranean-European section' spreads out towards the west from Indo-Malaysia to the Atlantic coast of the continent. This peninsular portion of the eastern hemisphere is the historical home of the White man, the field for the development of what we are in the habit of calling Caucasian civiliza-

tion. On the opposite side of the globe the western hemisphere points south between the two seas.

Having located the four races in their respective habitats, we should next determine how each racial region was originally occupied, and then note the ethnic effects produced by geographic peculiarities.

The human species was differentiated from the other anthropoids within Indo-Malaysia, where the climate was moist and warm and the surface of the ground covered with a tropical forest growth. Such were the surroundings that impressed themselves upon primeval man and established the original type. These conditions were continued on either side of the cradle-land toward the south along the equatorial belt of the eastern hemisphere, which then stretched uninterruptedly from the west coast of Africa, across the now partially submerged Indo-African continent, into Melanesia and Australia. The shifting of the thermal equator north and south of the geographical equator no doubt caused the climate of this intertropical belt to vary slightly during the ice-age; but after the final retreat of the glaciers no further changes occurred; so that, ever since, the environmental conditions of the eastern-equatorial region have remained to all intents and purposes the same as they were in tertiary times. The Negro descendants of the original inhabitants of these parts have thus been subjected since time immemorial to somewhat the same external influences as impressed themselves upon primeval man. It is natural, therefore, that the blacks should conserve the conspicuous characteristics of the ape-like ancestor and resemble the human prototype more closely than any other people. Ethnically the Negroes are considered the lowest of the four races of man; while geographically they may be characterized as the children of the tropical forest. There are, to be sure, minor differences among them, arising from different lines of heredity, variations of environment, migration and miscegenation; so that from the primitive Pygmy people living in the recesses of the tropical forest, the line of ethnic evolution may be traced through the pure Negroes, who occupy the central equatorial belt, to the mixed Negroid types which have come into contact with other races on the borders of the region. But despite these differences the Blacks may still be regarded as ethnically similar and grouped together under one racial category; for, if we confine ourselves to general characteristics, the typical Negro can readily be distinguished from his human fellows by his black skin; his short curly hair, which is flat in cross section; his long head with protruding jaws, his flat foot, his broad nose and his round black eyes.

The rest of the races of mankind were differentiated within the northern hemisphere. Being affected from the first by the varying environment of the glacial era, these northern emigrants were influenced by different conditions from those to which their ancestors

had become accustomed in the Indo-Malaysian abode. Furthermore, upon the final retreat of the ice the people of the north became marked off from the inhabitants of the south by climate bounds. Regarded collectively, therefore, Mongols, Caucasians and Americans alike may be distinguished from the tropical Negroes as products of the temperate zone. The several stocks that migrated northward from the Indo-Malaysian abode were, however, separated from each other from the start by the mountain barriers and open seas that intervened between the different lines of march. Thus though subjected to somewhat the same climatic conditions during the period of dispersion, upon settling in their respective habitats, the geographic groups were influenced by different surroundings. As a result, ethnic diversity was established along the northern latitudes, and the three temperate races became separated from one another by topographic differences. Taking this as our clue we may go back again to the original point of departure and follow the several lines of northerly dispersion in detail.

As was indicated above, the Indo-Malaysian cradle-land is cut off from the Asiatic area by the Himalayan line. Passage was possible, however, between the longitudinal ranges of Cochin-China, and, judging from the remains that have recently been discovered in this mountainous region, it is probable that primeval man proceeded northward along these lines during the interglacial epochs. The effect of the Himalayan barrier was, therefore, not so much to prevent migration into the continental area, as to shut the Asiatic immigrants in, and separate them from the inhabitants of the south. Those that remained in this region—Mongols in the forming—must, accordingly, have been subjected for long ages to the influences of their own surroundings.

This Asiatic area is not characterized by any such uniformity as the eastern equatorial region, but as nature has operated here upon so stupendous a scale, there is still a certain sameness in the salient features of the environment. Speaking generally, Asia is a continental territory, made up for the most part of bleak plateaux and deforested steppes. Such at least were the prevailing conditions which impressed themselves upon the majority of the original inhabitants and constituted the basic type. The Mongolians may thus be regarded as the product of temperate plains, much as the Negroes were considered to be the children of the tropical forest.

Here as elsewhere, however, variations from the characteristic environment made for corresponding modifications of the normal ethnic type. Being of such enormous extent and cut off on two sides from the sea, the climate of the Asiatic section is predominantly continental. Nevertheless, as the region stretches from the Arctic circle to the tropic of Cancer, and rises in altitude from 100 feet below to 25,000 feet above sea-level, there is naturally a wide range of temperature within

its borders. Topographically, the Asiatic section is dominated on the south by the Tibetan table-land, culminating in the Pamir region, called the 'roof of the world,' from which the land falls off rather abruptly on the west, and more gradually toward the north and east to the level of the sea. The bleak plateaux are thus succeeded by grassy plains and deforested steppes, which in turn are bordered by a comparatively narrow Tiaga, or wooded belt, extending to the Arctic Tundra and in places to the Pacific shore. The heart of the continent contains deserts and enclosed seas, while the surrounding lands are furrowed by forest-bordered streams flowing to the north, and by more open rivers of uncertain course draining toward the east. In consequence of these climatic and topographic differences, the Mongolic race has in the course of time become subdivided into a number of geographic groups. There are plateaux people, desert folk and steppe tribes, forest dwellers and typical Hyperboreans, and the settled inhabitants of the eastern valleys. Migration has moreover been succeeded by miscegenation, so that the lines of heredity and environment have become confused. Withal, however, enough Mongolian traits have persisted everywhere over the region, and during all the centuries that have elapsed since the original type was constituted, to allow us to set the Yellow people in a separate racial category, and distinguish the typical Mongol from his human fellows by his round head with high cheek-bones; the texture and pigment of his skin; his coarse straight hair, which is cylindrical in cross section; his thin colorless lips; and his small oblique black eyes.

South of the Himalayan line the peninsular portion of the old world spreads out like a fan from the Indo-Malaysian cradle-land to the Atlantic coast of the continent. On the east, the Indian section of this territory is connected with the equatorial region through the southern peninsulas, which once formed part of the Indo-African continent; but cut off from the Asiatic area by the lofty Himalayan range. On the west the conditions are reversed, the Mediterranean and European sections of this territory being cut off from the equatorial region by the Sahara, and connected with the Asiatic area through what is called the open gateway of the east, lying between the Ural mountains and the Caspian sea. There was access to the Indo-Mediterranean-European section, therefore, from two sides; from the equatorial region on the southeast, and from the Asiatic area on the northwest. The ancestry of the so-called Caucasians can accordingly be traced back to two sources. From the southeast, dolichocephalic Negroids pushed westward from Indo-Africa into the Mediterranean region and overran Europe in very early times. Somewhat later successive streams of brachycephalic Asiatics poured in through the open gateway of the east and mingled with the primitive inhabitants of these parts. From

the standpoint of heredity, therefore, the White people constitute a derived race, combining Negro and Mongolic affinities. For the rest, however, they are the products of their peculiar surroundings.

Unlike the other two regions, the peninsular portion of the old world contains an almost infinite variety of environments. With its apex in the subtropics, this triangular territory stretches out towards the northwest across the warm temperate, temperate and cold temperate zones, and consequently offers a series of climate transitions without striking contrasts. Topographically also the Indo-Mediterranean-European region is diversified throughout with deforested and forested river valleys, indented sea-shores, deserts, plains and steppes, alps and mountains, woodlands and dales, heaths and downs—in fact, with pretty nearly all the varied features the surface of the earth affords. On account of this diversity of environmental conditions, it is difficult to characterize the Indo-Mediterranean-European region as a whole. Negatively, at least, it may be distinguished from the equatorial belt by its temperature, and from the Asiatic area by its topography. Considered positively, its oceanic climate and its peninsular structure constitute its most striking characteristics. It should furthermore be noticed that the region is subdivided into three interconnected sections: The Indian section, which proceeds by insensible steps out of the eastern-equatorial region; the European section, which opens out of the Asiatic area; and the Mediterranean section, lying between, which combines the characteristics of the other two sections, and still possesses certain peculiarities of its own.

With this lack of environmental uniformity goes a corresponding diversity of ethnic types. The influx of original races from either side, migrations to and fro through the length and breadth of the land, adaptation to special surroundings, and the mingling of the blood of different peoples, have all contributed to the existing complexity. Stock has been added to stock in this way, and ancestral lines have become so confused that the ethnic diversity among the inhabitants of the Indo-Mediterranean-European region is as great as its environmental variety. Thus though it is easy enough to distinguish the white man from his human fellows, it is difficult to describe a typical Caucasian. In fact, only one physical characteristic runs through the whole race, namely, the hair, which is predominantly wavy and always oval in cross section. Generally speaking the Caucasian's features are also more regular than those of other people and his eyes are usually set straight. For the rest, amid the existing diversity, the most that can be done in the way of classification is to establish three types of white men, corresponding roughly to the three sections into which their territory is divided. In the center, there is the olive-skinned, brunette, Mediterranean type, which was originally recruited from the

southeast, but which has in the course of time become differentiated from the Negroids and adapted to its peculiar surroundings. Toward the northwest we find the florid-skinned, blond-haired Europeans, whose ancestors are Mediterraneans and Asiatics, but whose distinguishing characteristics were undoubtedly acquired during the course of their wanderings across the plain lands between the Pamir region and the Baltic. In the southeast section finally, dwell the swarthy-skinned, black-haired Indians, who came down from the northern plain lands during prehistoric days and established their supremacy over the scarcely differentiated black people of the peninsula. These distinctions are not to be taken too definitely, however; for even as the three sections of the Indo-Mediterranean-European section are interconnected, so the corresponding ethnic types are blended along the lines of transition, in such a way that it is as easy to pass from diversity to unity as from unity to diversity in considering the characteristics of the Caucasians.

Before leaving the eastern hemisphere to consider the fourth racial region on the other side of the globe, we should take a hasty survey of the insular region of Oceania and determine the ethnic affinities of the South Sea Islanders. These islands of the Pacific are so scattered, and differ from one another so widely, that they cannot be said to constitute a separate racial region. The most that can be done in the way of classification, therefore, is to divide the archipelagoes into groups, establish their relations with each other, and indicate their connections with the mainland.

Topographically the islands may be divided into two classes: continental and oceanic. The continental islands are adjacent to the mainland and stretch out along the equator toward the east and southeast. The oceanic islands, on the other hand, are grouped between the tropics in isolated archipelagoes, extending more than halfway across the Pacific. The lines of entry into this insular region lead back to Indo-Malaysia, the cradle-land of mankind and the point of intersection of the three racial regions of the old world. Oceania was, accordingly, peopled from three sources, successive waves of Negro, Caucasic and Mongolic migration coming together in Indo-Malaysia and spreading out again over the islands of the Pacific.

The negro dispersion occurred first, probably in the early days when the eastern-equatorial region still extended uninterruptedly far out into the South Sea. As the configuration of the globe assumed its historic form, many of the earlier land-bridges were broken, leaving the blacks to become adapted to different insular environments. But as the islands occupied were for the most part continental and situated under the equator, the surrounding conditions differed but slightly from those prevailing throughout the eastern-equatorial region. As a

result, the Oceanic negroes are ethnically similar to their African relatives. There is even the same succession of types, running from the pygmy Negritoes of Borneo and the Philippines, through the Negroes of Papua and Melanesia, to the Negroids of Micronesia. The Australians constitute the only exception. The racial affinities of this primitive people are somewhat doubtful, though they are in all probability derived from Negro stock. The Australians have lived so long isolated in their island continent, however, that in the course of time they have developed certain ethnic peculiarities.

Oceania is still connected through Malaysia with Indo-China. The Golden peninsula, in turn, is joined on the west with the Indo-Mediterranean-European region, and open on the north to the Asiatic area. During prehistoric times, migrations proceeded along both these lines in successive stages toward the east. From the peninsular portion, people belonging to the white race—Indonesians they are collectively called—passed through Malaysia and proceeded thence (probably in canoes or perhaps in proas) to the scattered islands of Polynesia. Monuments and stone records still mark the path of this Indonesian dispersion even as far as Easter island. Miscegenation with Negro natives doubtless occurred along the route, accompanied by adaptation to the different environments; but withal, the original type has been preserved, so that the surviving Indonesians, classified geographically as Polynesians, still show distinct Caucasic characteristics. The Mongols who pushed south somewhat later from the Asiatic area into the Golden peninsula became deeply impregnated with Indonesian blood in these parts. The mixed Malay race thus constituted subsequently spread out through the adjacent islands and eventually established their supremacy over Malaysia. Some of them, notably the Bujis, became a sea-faring folk, and by establishing commercial connections with the surrounding islands, extended Malaysian influence still further across the Pacific.

During the middle ages Saracen traders reached these parts from Arabia, and from very early times Chinese emigrants have continued to establish out-post settlements upon the littoral islands of Asia; but with these later influences we have not at present to deal. It is enough to know that the inhabitants of Oceania trace their ethnic origin to the three great races of the old world. In the tropical continental islands of Melanesia, the Oceanic Negroes predominate. Scattered over the oceanic islands of Polynesia are the Indonesian descendants of an ancient Caucasic line. Throughout Malaysia the Mongolic Malays prevail. The island continent of Australia contains a peculiar population, probably derived originally from Negro stock, while the tiny islets of Mikronesia support scanty settlements of mixed Melanesian-Polynesian people.

Entry into the fourth racial region was not from Indo-Malaysia but from the Arctic peninsulas of the eastern hemisphere. During the period of dispersion, continuous connections probably existed along these high latitudes, joining America with northwest Europe, on the one hand, and with northeast Asia, on the other. It was possible, therefore, during these early ages, for dolichocephalic Mediterranean people to continue the course of their northwesterly migrations until they reached the Atlantic shores of the new world; and for brachycephalic Asiatics to pursue their way northeastward until they came to the Pacific coast of the continent. That the western hemisphere was originally occupied in this manner by emigrants from Europe and Asia appears probable from the prevalence among the American aborigines of the long-head type in the east and the broad-head type in the west. The incursion along the Atlantic could not have lasted as long as that proceeding by way of the Pacific, for the ancient land-bridge joining northwest Europe with northeast America was broken long before the prehistoric period, and the islands left between were too far apart to afford further access from this direction. On the Pacific side, however, the old miocene bridge, with its temporary glacial extensions, probably endured until quaternary times, and after this, approaches still remained across the narrow Behring strait and along the Aleutian island chain. We should think of Asia, therefore, as the source of the main stream of migration that spread southeastwards over the new world.

In these early days, before the knowledge of ocean navigation, America was not as now a *Durchgangsland,* but rather a *cul-de-sac.* There was entry on either side from the north, but no exit in any other direction. The aboriginal people pouring in from above must, therefore, have been pushed down by the later comers through the constricted central space, like the sands in an hourglass, to spread out along the equator and become contracted again in the apex of the continent. Moreover, as the main stream of migration proceeded from Asia, the emigrants from Europe were probably confined from the first to the eastern edge of the hemisphere. Cut off completely from further contact with other people, the American aborigines, long-heads and round-heads alike, were henceforth subjected to the influences of their new surroundings and modified accordingly.

Geographically speaking, the American continent differs from the other regions of the earth, and at the same time possesses certain positive characteristics of its own. This isolation of the western hemisphere, taken together with such environmental uniformity as exists within its borders, had the effect of differentiating the aboriginal inhabitants from their European and Asiatic ancestors and blending them gradually into one racial variety, possessing pronounced Oriental affinities.

Topographic and climatic differences led, however, to lines of minor ethnic variation, which, for environmental reasons, cross each other at right angles. Topographically considered, the western hemisphere combines longitudinal uniformity with latitudinal diversity, so that in this respect the two sections of the continent are very much alike. Both North and South America have their mountain ranges along the west and the mural masses of each section are succeeded by deforested plains and forested river valleys extending to the Atlantic coast. As a result, there is a corresponding variation of ethnic types running through both continents from west to east, showing more or less marked distinctions between the men of the mountain, the men of the plain, the men of the forest and the men of the shore. Owing to its extension across almost all the degrees of latitude, the western hemisphere offers, on the other hand, an extreme longitudinal range of climate, so that in this respect there is a striking difference between the two Americas. Both triangular sections have their bases on the north and their apexes turned towards the south in such a way that the northern continent is mostly temperate and the southern continent predominantly tropical. As a result, there are likewise lines of ethnic variation running along the longitudes, which distinguish the inhabitants of the northern or temperate continent from the inhabitants of the southern or tropical continent. From the fact that they cross each other at right angles, however, these longitudinal and latitudinal variations tend to neutralize each other to a large extent and leave a relatively uniform type. It is possible on this account, despite the diversity that exists among the American aborigines, to distinguish the Red man from his human fellows by his brown or copper-colored skin; his lank black hair, which is nearly round in cross section; his deep-set beady black eyes; his aquiline nose; his massive jaws; and his finely formed figure.

There has been no attempt in the foregoing, either to make an exact analysis of the ethnic make-up of mankind, or to follow the process of varietal differentiation in detail. The sole purpose of the enquiry has been, by combining the analytical and geographical methods of investigation, to indicate the probable order of racial ramification and to determine in a general way under what environmental conditions the ethnic differentiation of mankind occurred.

WERE THE EARLIEST ORGANIC MOVEMENTS CONSCIOUS OR UNCONSCIOUS?

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THERE are now current two general theories of the place of mind in nature. The one of these, and the one which it is easier to state in precise terms, regards the processes of the material universe (including those of the physical organism) as a closed chain of cause and effect, which is altogether removed from any psychical influence. Mental process is a concomitant of certain highly complex material processes, but not anything that affects these processes themselves. Whether or not it is a constant concomitant, and thus a valid index or symptom of the nature of the underlying material processes, is a question which science must settle by appeal to the facts. Modern psychology answers it in the affirmative, though she offers no explanation—cannot, in the nature of the case, offer an explanation—of the 'why' of the connection. Mind exists; mental processes run their course in constant parallelism to bodily processes; they never interfere with these processes. This is the first view, and the view which I myself, at the present time, consider to be the more tenable.

The alternative theory regards mind as capable of causal interaction with body. Mind and body have developed together, and it stands to reason that they mutually influence each other. This is a common sense point of view; it seems, at first sight, to have everything in its favor, and to be just as intelligible as the other.

We must, however, go a little deeper. And, in order to keep things clear, let us give the theory of interaction a more concrete form. One of the strongest arguments in support of the theory, or perhaps we might rather say one of its necessary implications, which appears to many psychologists to be borne out by the facts, is that 'consciousness' has a 'survival value,' that mind is a factor in organic evolution. Now we must sharply distinguish between two different uses of the term 'consciousness,' which are oftentimes confused by the advocates of interaction. Consciousness may mean knowledge or awareness, our acquaintance with the world about us, or it may mean simply (as on the first theory it always must mean) a complex of mental processes. In the former meaning, it covers the great functions of cognition, memory, reasoning, imagination, etc. And this is the point at which confusion enters. Cognition, memory, and the rest, are not purely

mental functions, but functions of the mind-brain union, of the total psychophysical organism. It is not a detached mind that knows and remembers, but the living organism, embodied soul and ensouled body. We never find reasoning where there is no mind; but neither do we find it where there is no body. If, then, I am allowed to interpret 'consciousness' in this way, I can, although I hold the theory of concomitance, subscribe to everything that the interactionist says of the survival value of consciousness. An organism that remembers will certainly, other things equal, get the better, in the struggle for existence, of an organism that cannot remember. Only, the real question remains: does the remembering animal survive because it consciously remembers, or because its brain is capable of those complicated processes which form the substrate of conscious memory? Parallelism maintains that the concomitant mental processes make no difference to the result. Interactionism has to maintain, in this concrete form of the 'survival theory,' that the mental process as such is an aid to evolution; that the function which is psychophysical helps the organism onwards, on that account, more than the function which is physical; that consciousness, just because it is mental process, furthers life and progress. On any other formulation than this parallelism and interaction join hands,—for any other formulation begs the whole question. And in this formulation, as asserting that a mental process may be interpolated as a causal link between two physical processes, the theory of interaction seems to me to be weaker than its rival.

The foregoing paragraphs are not intended to convert or convince the reader; each theory has its peculiar difficulties, the discussion of which here would lead me too far afield.* They are merely a brief expression of a scientific creed. Such an expression is, I think, a necessary prolegomenon to the special problem of this paper.

One other prefatory remark must be made. I shall often speak, in what follows, as if the problem of the origin and development of organic movements were identical with that of the origin and development of mind at large. In many contexts this identification holds. For it is an universally admitted fact—sometimes raised to the dignity of a law, as the 'law of dynamogenesis'—that there can be no intake on the organism's part without corresponding output; the action of any appreciable stimulus has its reaction of motor discharge. The simpler the organism, the clearer is this correlation; but it holds through-

* A good popular account of psychophysical parallelism is given by H. Ebbinghaus, *Grundzüge der Psychologie*, I., i., 1897, 41–47. The strongest attack made upon the theory in recent years is that of C. Stumpf's 'Eröffnungsrede,' printed in the 'Bericht über den III. internationalen Congress für Psychologie,' 1897. I say nothing in the text of Interactionism as a static (opposed to genetic) theory. The reader must pardon this and other sins of omission, on the score of necessary brevity.

out.* It follows, then, that there can be no consciousness without movement, though there may, of course, be movement without consciousness.

If we turn, now, to the question of the character of the earliest organic movements, we find, again, that two views are current. It is maintained, on the one hand, that mind is as old as life. The first movement of the first organism must, then, if it exceeded a certain liminal extent, have been attended by some sort of consciousness. Let us say, in round terms, that the first locomotion of the first vagrant organism must have been accompanied by mental process. It is maintained, on the other hand, that the first movements are more akin to the movements that physiologists term 'reflexes,' direct and unconscious responses to stimulation; and that mental process appeared at some relatively high stage of organic development, when the conflicting demands upon the organism could no longer be met by such direct response, but led to tensions and inhibitions, in a word, to 'hesitancy' of movement. The parallelist will naturally incline to accept the first hypothesis; the interactionist, to accept the second. What are the arguments?

Let us look, first of all, at some of the arguments for an unconscious first movement. (1) One of the most insistent is the appeal to the law of parsimony. If we can start organic movement with something like the reflex, it is urged, is it not our bounden duty to do so, and thus to work out our problem with the fewest possible terms? If life is conceivable without consciousness, ought we not so to conceive it, instead of dragging in a superfluous 'mind'? As a purely formal argument, the appeal to parsimony may be met by the counter-appeal to the law of continuity. It is no more impressive to say, in the abstract, 'Entia non sunt multiplicanda præter necessitatem,' than it is to say 'Natura non facit saltum.' But the argument is, of course, more than purely formal. It suggests, as adequate and as the simplest possible, a certain definite interpretation of the facts. It throws upon parallelism the burden of proving the necessity of mind at the first appearance of life.

The parallelist might meet this challenge by raising the previous question. The facts to be interpreted are natural phenomena, and nature is not bound by any law of parsimony. Indeed, the prodigality of nature is fully as evident as her frugality: witness the prolongation of life beyond the period of reproductiveness, the enormous range of our sensations of tone, the genius lavished on pure mathematics. It is at least possible that, in the present instance, nature is less economical in action than we strive to be in thought; that, in giving us life, she

* *Cf.* J. M. Baldwin, 'Mental Development,' etc., Methods and Processes, 1895, 166.

has given us mind into the bargain. It is, I say, at least possible. We know too little of the facts cited as analogical to be able to say more.

But there is another and a stronger objection. We know nothing of mind, at first hand, except as it exists in man. Elsewhere, we are forced to rely upon the 'objective criteria,' of which more presently. What right, now, has the interactionist to bring mind into the organic series at any point lower than man? Why is he not bound, under the law of parsimony, to keep mind out until its presence can be positively demonstrated? I think that the answer is plain; he is so bound, unless he can show cause for believing that mind, were it present, would be of service to the organism in the struggle for existence. As he has called upon his opponent to 'prove the *necessity* of mind at the first appearance of life,' so we might retort that he is himself bound to show the *indispensableness* of mind to the struggling organism. But we will let the more modest phrasing stand, and proceed to an examination of the arguments.

The *locus classicus* for the survival value of consciousness is Chapter V. of James' 'Principles of Psychology.' The arguments are three.

(*a*) "The brain is an instrument of possibilities, but of no certainties. . . . Its hair-trigger organization makes of it a happy-go-lucky, hit-or-miss affair. It is as likely to do the crazy as the sane thing at any given moment. . . . But the consciousness, with its own ends present to it, and knowing also well which possibilities lead thereto and which away, will, if endowed with causal efficacy, reinforce the favorable possibilities, and repress the unfavorable and indifferent ones."

The facts bear out this 'a priori analysis'; for

'consciousness is only intense when nerve-processes are hesitant.' (*b*) The phenomena of vicarious function 'seem to form another bit of circumstantial evidence.' "Nothing seems at first sight more unnatural than that [the remaining parts of the brain] should vicariously take up the duties of a part now lost without those *duties as such* exerting any persuasive or coercive force." (*c*) "If pleasures and pains have no efficacy, one does not see . . . why the most noxious acts, such as burning, might not give thrills of delight, and the most necessary ones, such as breathing, cause agony."

The first of these arguments is little less than amazing. It asserts that the brain, the central and ruling organ of the whole body, has been so far exempt from the influence of natural selection that it is 'indeterminate,' 'an instrument of possibilities,' 'as likely to do the crazy as the sane thing'! 'The natural law of an organ constituted after this fashion can be nothing but a law of caprice.' Does such 'a priori analysis' commend itself to the neurologist? I should rather say that the brain, combining as it does an immense structural complexity with great architectural simplicity, has been stably and determinately molded for the part which it plays in the economy of the organism; that it is a marvelously reliable organ, definitely disposed

for definite functions. I think that anatomy and physiology bear me out. And as for consciousness being intense only when 'nerve processes are hesitant': what of the plunge into cool water on a hot day? what of the enjoyment of music after a long æsthetic starvation? what of our grief at the loss of a dear friend?

The second argument I take to be misleading. Vicarious function has its limits. We can never see by aid of the auditory center, or hear by aid of the visual. But the brain is bilaterally symmetrical; its centers are arranged in a hierarchy, one above another; the connections of center with center, direct and indirect, are multitudinous. Vicarious function is thus, within wide limits, possible and natural; the excitation whose 'principal path' is blocked finds several 'secondary paths' still open. Let all the paths for a given form of excitation be blocked, however, and what happens? Here is the supreme occasion when consciousness might be useful; and consciousness does nothing.

The third argument requires a somewhat more detailed examination. It is an empirical law, a rule of average, that pleasant things are good for the organism, and unpleasant things bad. Pleasant things, things that we like, are things which, presented as stimuli, evoke movements of extension or approach; unpleasant things, things which we do not like, repel us,—we shrink from them. The usual explanation of the law is that organisms which (as psychical) liked and (as physical) reached out after things that were bad for them would, in the long run, be killed off. It is a condition of living that the things sought after shall, on the whole, be good for the seeker. The argument alleges that this explanation is insufficient. 'If pleasures and pains' as such 'have no efficacy,' there is no reason why their relation should not be reversed; why the things that are bad for us should not be pleasant, and the good things unpleasant.

I think that the argument, by its very formulation, assumes the causal efficacy which it is meant to prove. It assumes that a change of mental process must necessarily condition a corresponding change of motor reaction. Now there is good biological reason—psychology apart—why the things that are bad for us should not be sought after, and the things that are good for us neglected or repelled. But what mental process colors the 'sought after' and the 'repelled' is simply a question of fact. If it is the peculiar quality of pleasure and pain that we are asked to account for, I reply that we can no more explain this than we can explain why ether waves of a certain frequency correspond to the sensation quality 'red' and not to that of 'blue.' If it is the constancy of the mental accompaniment that is at issue—and this is suggested by the reference to an 'a priori rational harmony'—I reply that the constancy is a given fact, accepted by parallelist and interactionist alike, just as it is in the case of the colors. The argument, so far as I

have understood it, does not 'make sense,' except from the standpoint which it is supposed to recommend. And the instances do not help us. Breathing is not a source of such extreme pleasure, as things are, that a reversal of relations should make it an agony, and the nervous processes in burning are by no means hesitant, and ought, therefore, to yield nothing so intensive as delight.*

So far, then, the argument from parsimony seems to have little positive content. It simply asserts that the *onus probandi* lies with those who make mind and life coeval. Whether the parallelist can shoulder the burden we shall see later on. In the meantime, let me insist upon the limitation that attaches to both theories alike. The parallelist can never explain why life should be attended by mind. He thinks that there is evidence of the connection, but he cannot further account for it. The interactionist is apt to suppose that, by his appeal to parsimony, he has furnished an explanation of the appearance of consciousness; mind came upon the scene, when and because it was useful to the organism. The fallacy is obvious. The development of mind under the rule of natural selection is one thing; the question of the origin of mind is another, and is something that lies wholly beyond the ken of science.

(2) But we may leave the sphere of formal argument. The theory of originally unconscious movement finds factual support, it may be said, and support of the strongest kind, in recent experimental investigations. The movements of the lowest animals are not random and variable, but simple and stereotyped; they are, in many cases, even simpler than the reflex, as we ordinarily conceive of the physiological reflex; they may be referred to mere 'tropisms,' direct physico-chemical responses to physico-chemical changes in the environment. Nay more, the complicated activities of such highly developed organisms as ants and bees may be subsumed, with surprising completeness, under some such heading as the 'chemoreflex.'† Here is proof positive. What more can we ask?

We may ask, first, for a clearer recognition of the point of view from which these investigations have been made. The psychologist has no choice but to begin at the upper end of the organic scale—to begin with himself, and his own mind—and to work downwards, interpreting as he goes. The road is full of pitfalls; there is constant

* W. James, 'The Principles of Psychology,' 1890, i., 138 ff., 67 ff.; ii., 584, 591 f.

† I have in mind such investigations as those of A. Bethe, *Pflüger's Archiv*, lxx., 1898, 15, and H. S. Jennings, *Amer. Journ. of Physiol.*, ii., 1899, 311; *cf.* *Amer. Journ. of Psych.*, X., 1899, 503. The number of these studies is steadily increasing. On the following arguments, *cf.* E. Claparède, *Revue phil.*, 1901, 481 ff.

temptation to exaggerate the mental endowments of the lowest creatures, to make their minds miniature copies of the human. Romanes' books, for instance, show over and over again how a psychologist, working in the interests of mental evolution, may overestimate the range and complexity of the animal consciousness. Still, this is the one path that psychology can follow. The biologist, on the other hand, thinks his world, when he thinks consistently, in terms of physics and chemistry. He is also accustomed to think from below upwards. His natural tendency, then, is to carry physical and chemical principles as high in the scale of life as they will go. He has his inconsequences, as the psychologist has his exaggerations; and his besetting inconsequence is to admit the presence of mind in animals higher than those which he has himself examined. But science is not inconsistent because her representatives may sometimes nod. It is a postulate of mechanistic biology that physical and chemical principles will carry the biological student all the way, from the algæ to man. Consciousness does not fall within his horizon. Until, then, the interactionist has converted his biological colleagues to vitalism, and thence to the admission of mental process as an equivalent of physical energy, we must conclude that the two fields of enquiry, the psychological and the biological, do not overlap. There is no reason why the biologist, granted a steady increase of natural knowledge, should not some day reduce all the movements, say, of the monkeys, to physico-chemical terms, to a system of simple or complex 'reflexes.' That is what he is on the way to do. On the other hand, the reduction of all the movements of paramecium to a single 'reflex' type does not prove to the psychologist that the creature has not (or has not had) a mind. Biology and psychology, if I may change the metaphor, meet and pass on a double track. They do not collide, but neither do they turn out to be two halves of a single train of thought.

We may ask, secondly, for a clearer understanding of what has been called the 'objective criterion of mind.' The phrase is open to the objection that it contains a *contradictio in adjectivo;* how can there be an objective criterion of the subjective? But we may waive this, and assume that an empirical correlation is possible. Let us suppose, then, that biology and psychology agree to ask the question: How are we to tell, by watching a lower animal's movements, whether or not it has a mind? And let us suppose, further, that they are agreed upon their answer. The answer must be of this kind: If you see so and so, then you may infer the presence of consciousness. Beyond that, no answer has gone, and no answer can possibly go. Because this animal does this thing, it has a mind; this other animal does not do this thing, therefore —what? Therefore, we do not know whether it has a mind. It may not, of course, but then again, it may. The biologist, I repeat, may

multiply his tropisms till they cover the whole field of organic movement; he is only consistent in so doing, just as he is consistent in refusing to speak of 'visual perception' and in martyrising his linguistic consciousness to the term 'photo-reception.' But, though it rain tropisms, the psychologist may go without his umbrella.

However, when all is said, is there not at least a presumption in favor of the unconscious-movement theory? That is the theory adopted by the men who made the investigations; and, surely, they ought to know, if anybody knows. Would it not be good common sense to take their conclusions, instead of speculating about what may be? I have no great objection; save on that single score of scientific methodology, I have no objection. For it is one of the cardinal points of the theory which I hold, that a movement which at first was conscious may presently lose its conscious character; that the physical may in course of time replace the psychophysical. The fact, then, if it be a fact, that ants and bees are nowadays mere reflex machines will mean that they started out, so to say, with a certain endowment of mind, which they have lost in the process of adaptation to their special environment; and the similar fact that paramecium has its one stereotyped form of motor reaction to stimulus will mean that it, too, had at first its modicum of mind, which it has lost on its journey through the ages. The evidence for this view I have yet to give. If it be sound, then the automatism of the lower animals does not in the least degree affect the theory that mind is as old as life.

And now for the alternative theory,—which must, I suppose, always strike the biologist, more especially if he be physiologist, as fanciful and far-fetched; the theory that the first animal movements were conscious, and that all our present movements, the reflexes included, are the direct descendants of conscious movements. What is the evidence in its favor?

If we consider the facts of organic movement as they are presented in our own experience; if, following the rule of psychological enquiry, we set out from an examination of our own action and conduct; we find that the phenomena cannot be brought at once under the head of any single principle, but that they rather result from the joint operation of two different tendencies. On the one hand, we are continually enlarging our sphere of action; conduct grows more complex; new motives are formed, new adaptations made; there is a tendency towards more and more complicated or specific coordinations of movements. The realization of this tendency is always accompanied by consciousness, by the mental formations that are known, both in popular speech and in psychology, as choice, resolve, deliberation, judgment, doubt, etc. On the other hand, there is a tendency towards the simplification of movement; coordinations that at first involved corti-

cal activity are presently, as a 'habit' is formed, relegated to lower centers. And the realization of this tendency is accompanied by lapse or loss of consciousness. We learn to walk, to swim, to bicycle, to typewrite, to play a musical instrument, with conscious pains and effort. Later, if we practise enough, we do these things 'automatically,' unconsciously. We may typewrite correctly while our attention is wholly directed upon the meaning of our paragraph; we may play a musical composition correctly while we are engaged in an absorbing conversation. The original impulsive or selective or volitional action has become automatic. We can, of course, bring its terms back to consciousness; we can stop and 'think' that we are typewriting or playing the piano or bicycling; but if we do this, the movements become hesitating and may be seriously deranged. If the natural tendency takes its course, we finally reach a form of movement which (except that we know its course of development) is not distinguishable from the physiological reflex.

Here is a bit of positive and unmistakable evidence. It is possible, in the life history of the individual, for conscious movements to pass over into unconscious. Not only is it possible: it is a regular occurrence. From the biological point of view, it is eminently useful; the simplification of response to stimulus, its relegation to lower nervous centers leaves the organism free for further adaptations. Is there not some ground, then, for generalizing the facts, and saying that, probably, *all* unconscious movements have developed from conscious? This is what Wundt has done, in his statement that 'the reflexes are voluntary actions that have become mechanical.* Only, his terminology is at fault, for the antithesis of the voluntary is not the mechanical (all actions, biologically regarded, are mechanical), but the unconscious action; and the antithesis of the reflex is not the voluntary but the complex, coordinated action. So difficult is it, even when one's thought is scientifically clean, to avoid the language of 'common sense'!

I think that the reader who has recognized the weakness of the opposing theory will take great comfort in this piece of undisputed fact, and will be willing to generalize it farther than the logical canons warrant. To myself, brought up in the faith that mind developed somehow and appeared somewhere after the birth of life, and always unsuccessful in my attempts to reconcile this faith with reason, Wundt's counter-statement came as a real illumination. Nevertheless, as it stands, it is nothing more than an argument from analogy; we argue from the individual to the race. Is there no evidence from the race itself?

* W. Wundt, *Grundzüge der physiologischen Psychologie*, ii., 1893, 591. *Cf.* the historical discussion, 591–593, and *Philos. Stud.*, i., 1883, 354 ff.; also J. Ward, art. *Psychology*, Encycl. Brit., 9th ed., 43, col. *a*.

We find a little—as much, perhaps, as we have a right to expect. There is a class of movements, familiar to every one who has read Darwin's 'Expression of the Emotions in Man and Animals,' which are known in psychology as 'expressive' movements. Such are the opening of mouth and eyes in surprise, the frown and clenched fist of anger, the play of the facial muscles in joy and sorrow. These movements belong to various psychological classes, volitional, selective, impulsive, reflex. But there are among them certain reflexes—primary reflexes, not automatic actions or 'secondary' reflexes of the kind just described—that can only be explained as the unconscious descendants of earlier impulsive actions. The face of proud contempt reflexly 'curves a contumelious lip.' What does the movement mean? Why, it lays bare the canine teeth; it is the human counterpart of the snarl of dog or wolf; it is the last reflex or unconscious remnant of a coordinated or impulsive action which, somewhere or other in our not remote ancestry, preceded the movements of actual attack. The deer bounds away when it hears the hounds, and we 'jump' when we are startled; the sitting bird crouches on its nest when danger approaches, and we wince or shrink when we are frightened or censured. The connection is obvious; the activities are related; but the action which formerly was conscious has become, in us, a mere 'automatism.' Instances of this sort might easily be multiplied.* The facts are admitted, and their explanation accepted, by psychologists of all schools. But here is evidence of the derivation of unconscious from conscious movement, not in the life history of the individual, but in that of the race.

In both of the cases which we have discussed, consciousness has shown itself to be chronologically prior to unconsciousness. Are there any known cases to the contrary? Have we any instance of an action which, unconscious in the lower animals or early in our own lives, later becomes conscious? Have we any hint of a tendency in this direction? On the former count, as regards the animals, the appeal must lie to the 'objective criterion' of mind, and therefore to biology as well as to psychology. I can only say that the psychological evidence is negative, and that I have not myself—speaking, however, as a layman in biology—come across any positive indications in biological literature. On the latter, as regards ourselves, I find no evidence either in psychological

* It would be especially interesting to examine from this point of view the movements of the new-born infant. The position taken in the text is, I think, supported by, *e. g.*, the mimetic facial reflexes, and by the various atavistic reflexes (hanging from stick or finger, swimming movements, etc.). But a full consideration of all these movements would require a separate paper. On the other hand, the fact that in the higher animals the reflexes are imperfect at birth, and take a little time to 'harden'—a fact which has been rightly emphasized in several recent studies of animal behavior—does not seem to touch the present argument one way or the other.

literature or in my own experience. *Omne consciens e conscienti* is the law of conduct known to the psychologist. It may be retorted that the negative evidence is worth very little, since, *e. g.*, we believe that life evolved from inorganic matter, and yet no one has seen the not-living pass over into the living. I reply that the evidence is at least negative, that is, is not positive; and that, although we have not built up living protoplasm from dead matter, we have at least gone a good way towards it.

There is another point. The automatic actions that take shape in the course of the individual life have upon them the marks of appropriateness, of 'purposive' response to stimulus. They are relatively precise and clean-cut; they subserve some one end, or some set of interrelated ends. Appropriateness and precision are also, notoriously, characteristic of the physiological reflexes. They are similarly characteristic, we are told, of the tropisms and stereotyped reactions of the lowest forms of life, so that these are often spoken of as 'reflexive.' Is not this item of internal evidence worth something? Is it not probable that things which are so much alike have had a similar history? For it must be remembered that, however simple the organism which we are examining, it is still not a primitive organism; its history is, presumably, at least as long as the history of man. Not until we see the organism take shape from its inorganic constituents, and note the first reactions of the living mass, shall we have direct evidence of the nature of primitive movement; but by all analogy, that movement will not be precise and clean-cut, but vague and clumsy, indefinite and irregular. It is surely reasonable to suggest that the two tendencies which we find in ourselves, and which (on the testimony of expressive movements) are also operative in the race—the tendency towards new coordination and progressive adaptation, with consciousness, and towards specialized and stationary adaptation, without consciousness—were present from the very beginning; that the rudimentary organism might, as circumstances dictated, follow either of two paths, the downward path to static adjustment, by reflexes, or the upward path to dynamic adjustment, by conscious and coordinated action; and that in following the first path, it forever lost the power of higher development, while, in following the second, it still retained the power of fixing stably the reactions whose modification was unnecessary. Paramecium would then have lost the faint flicker of mind with which its original ancestor was endowed, and, losing therewith the possibility of coordinated movement, would have remained paramecium. But a primitive organism of like endowment, living under different conditions, and retaining both mind and the correlated physical adaptability, would have become man.

Still the opposing arguments will not down. If consciousness disappears as soon as adjustment to surroundings has become easy, why may it not have appeared as soon as adjustment became difficult? Why

may it not have developed late, when the difficulties of living called for a new aid to life? Why may we not return to the belief that mind has a survival value?

I reply, as I have replied in another connection, that the formulation of the question begs the issue. The question assumes that there is a causal connection between biological adaptation and consciousness. Since the facts can be formulated both in biological and in psychological terms, without lapse or break in the separate series of material and mental processes, the proof of survival value must be sought elsewhere. We have considered the evidence, and found it wanting. But we can, also, meet the question on its own terms. We may answer that the difficulties of adjustment were present from the outset, nay, must have been peculiarly pressing at the outset, when life was young and inexperienced; so that mind must also have been present from the first, and could not disappear until adjustment had already proceeded some little distance. Taken in the abstract, the one possibility is as likely as the other. There is, however, a direct answer which—if we bear in mind the limitations of theory at large—seems to be satisfactory. Mind appears with life. At first, there is no differentiation of functions; mind and life are uniformly coextensive. Later, with growing complexity of the organism, come differentiation of functions and the development of a central coordinating organ. If mind and life run parallel to each other, we must suppose that mind has also suffered differentiation, and that the supreme consciousness of the organism now accompanies the functions of the supreme organ. But this is what we find. There is, in strictness, no evidence of a complete 'disappearance' of mind; our own reflexes and automatic actions, though not attended by our consciousness, may have a consciousness of their own. This hypothesis has, in fact, recommended itself to many investigators.*

This last objection, then, does not shake our position. Have we, now, shown the 'necessity of mind at the first appearance of life?' We have at least made its presence so reasonable and probable that we need stand in no fear of the law of parsimony. But the recurrence of the counter-arguments at the very end of our enquiry is suggestive. It reminds us that we have been dealing, throughout, with inferences and probabilities, not with demonstrations and mathematical certainties. And an argument from probability is like an india-rubber ball; you hit it, and it may fly away, or it may return to you, all the more vigorously the harder you hit. So far from convincing the reader, this paper may simply prompt him to refutation and rebuttal. All the better—provided only that he adduce new arguments.

* *Cf., e. g.*, E. F. W. Pflüger, Müller's *Arch. f. Anat.*, 1851, 484–494.

TRUST DEED BY ANDREW CARNEGIE, CREATING A TRUST FOR THE BENEFIT OF THE CARNEGIE INSTITUTION, OF WASHINGTON, D. C.

I, Andrew Carnegie, of New York, having retired from active business, and deeming it to be my duty and one of my highest privileges to administer the wealth which has come to me as a Trustee in behalf of others; and entertaining the confident belief that one of the best means of discharging that trust is by providing funds for improving and extending the opportunities for study and research in our country; and having full confidence in the gentlemen after named, who have at my request signified their willingness to carry out the trust which I have confided to them:

Therefore, I have transferred to these, the Trustees of the Carnegie Institution of Washington, ten millions of registered five per cent. bonds of the United States Steel Corporation, the names of said Trustees being as follow:

Ex officio:

The President of the United States.
The President of the Senate.
The Speaker of the House of Representatives.
The Secretary of the Smithsonian Institution.
The President of the National Academy of Sciences.

John S. Billings, New York.	Seth Low, New York.
William N. Frew, Pennsylvania.	Wayne MacVeagh, Pennsylvania.
Lyman J. Gage, Illinois.	D. O. Mills, New York.
Daniel C. Gilman, Maryland.	S. Weir Mitchell, Pennsylvania.
John Hay, District of Columbia.	William W. Morrow, California.
Abram S. Hewitt, New Jersey.	Elihu Root, New York.
Henry L. Higginson, Massachusetts.	John C. Spooner, Wisconsin.
Henry Hitchcock, Missouri.	Andrew D. White, New York.
Charles L. Hutchinson, Illinois.	Edward D. White, Louisiana.
William Lindsay, Kentucky.	Charles D. Walcott, District of Columbia.

Carroll D. Wright, District of Columbia.

The said gift is to be held in trust for the purposes hereinafter named or referred to, that is to say, for the purpose of applying the interest or annual income to be obtained from the said bonds or from any other securities which may be substituted for the same—for paying all the expenses which may be incurred in the administration of the trust by the Trustees, including in said expenses the personal expenses which the Trustees may incur in attending meetings or otherwise in carrying out the business of the trust; and, second, for paying the sums required

by the said Trustees to enable them to carry out the purposes hereafter expressed. I hereby confer on the Trustees all the powers and immunities conferred upon Trustees under the law, and without prejudice to this generality the following powers and immunities, viz.: Power to receive and realize the said bonds, and the principal sums therein contained and the interest thereof, to grant discharges or receipts therefor, to sell the said bonds, either by public sale or private bargain, at such prices and on such terms as they may deem reasonable, to assign or transfer the same, to sue for payment of the principal sums or interest, to invest the sums which from time to time may be received from the said bonds on such securities as trustees are authorized by the law of the State of New York, Pennsylvania, or Massachusetts, to invest trust funds, and also on such other securities as they in the exercise of their own discretion may select, and to alter or vary the investments from time to time as they may think proper; and I hereby expressly provide and declare that the Trustees shall to no extent and in no way be responsible for the safety of the said bonds, or for the sums therein contained, or for the securities upon which the proceeds of the said bonds may be invested, or for any depreciation in the value of the said bonds, or securities, or for the honesty or solvency of those to whom the same may be entrusted, relying, as I do, solely on the belief that the Trustees herein appointed and their successors shall act honorably; and I further hereby empower the Trustees to administer any other funds or property which may be donated or bequeathed to them for the purposes of the trust; and I also empower them to appoint such officers as they may consider necessary for carrying on the business of the trust, at such salaries or for such remuneration as they may consider proper, and to make such arrangements, and lay down from time to time such rules as to the signature of deeds, transfers, agreements, cheques, receipts, and other writings, as may secure the safe and convenient transaction of the financial business of the trust. The Committee shall have the fullest power and discretion in dealing with the income of the trust, and expending it in such manner as they think best fitted to promote the objects set forth in the following clauses:

The purposes of the trust are as follows, and the revenues therefrom are to be devoted thereto:

It is proposed to found in the city of Washington an institution which, with the cooperation of institutions now or hereafter established, there or elsewhere, shall in the broadest and most liberal manner encourage investigation, research, and discovery; show the application of knowledge to the improvement of mankind; provide such buildings, laboratories, books, and apparatus, as may be needed; and afford instruction of an advanced character to students properly qualified to profit thereby.

Among its aims are these—

1. To promote original research, paying great attention thereto as one of the most important of all departments.

2. To discover the exceptional man in every department of study whenever and wherever found, inside or outside of schools, and enable him to make the work for which he seems specially designed his life work.

3. To increase facilities for higher education.

4. To increase the efficiency of the universities and other institutions of learning throughout the country, by utilizing and adding to their existing facilities and aiding teachers in the various institutions for experimental and other work, in these institutions as far as advisable.

5. To enable such students as may find Washington the best point for their special studies to enjoy the advantages of the museums, libraries, laboratories, observatory, meteorological, piscicultural, and forestry schools, and kindred institutions of the several departments of the Government.

6. To ensure the prompt publication and distribution of the results of scientific investigation, a field considered highly important.

If in any year the full income of the trust cannot be usefully expended or devoted to the purposes herein enumerated, the Committee may pay such sums as they think fit into a reserve fund, to be ultimately applied to those purposes, or to the construction of such buildings as it may be found necessary to erect in Washington.

The specific objects named are considered most important in our day, but the Trustees shall have full power, by a majority of two-thirds of their number, to modify the conditions and regulations under which the funds may be dispensed, so as to secure that these shall always be applied in the manner best adapted to the changed conditions of the time; provided always that any modifications shall be in accordance with the purposes of the donor, as expressed in the trust, and that the revenues be applied to objects kindred to those named, the chief purpose of the founder being to secure if possible for the United States of America leadership in the domain of discovery and the utilization of new forces for the benefit of man.

In Witness Whereof I have subscribed these presents, consisting of what is printed or typewritten on this and the preceding seven pages, on the twenty-ninth day of January, nineteen hundred and two, before these witnesses.

Andrew Carnegie.

Witnesses:

Louise Whitfield Carnegie.
Estelle Whitfield.

SCIENTIFIC LITERATURE.

POPULAR BOOKS ON EXTINCT ANIMALS.

If 'Dragons of the Air,' by H. G. Seeley, is not in quite so popular a vein as its title might indicate it is none the less a clear, comprehensive and interesting account of that remarkable group of reptiles, begging Professor Seeley's pardon, known to science as pterodactyls. No one is better qualified than Professor Seeley to write of them, as his acquaintance with these flying dragons is of many years standing, and he has made them the objects of special study. He tells us that he has attempted to show how a naturalist does his work and illustrates the methods of the paleontologist by briefly comparing the various parts of existing flying creatures with one another and applying the information thus gained to the study of the skeleton of the pterodactyls. Part by part the various portions of this skeleton are passed in review, and we are told the more important variations found in the widely varying members of the group and between them and other flying animals. Then, after a chapter devoted to evidences of animals' habits, from which the reader may learn how the conclusions regarding the food, covering and flight of pterodactyls have been reached, we are introduced to the various species that have existed at different periods of the earth's history. In connection with this are given some restorations of the more remarkable of the dragons of the air, including the extraordinary *Dimorphodon* with a head bigger than its body. Accompanying these restorations are plates showing the specimens on which they are based, and the skeletons built up from these specimens. Most of the figures represent the animals as running on all fours, an attitude that is questioned by some of our paleontologists, notably by Dr. Williston, who considers that they walked on the hind legs alone and that the great *Ornithostoma* in particular could not possibly have used its fore limbs as legs. The concluding chapters contain a discussion of the relations and origin of the pterodactyls and, from what has been said in other parts of the book, we are in a measure prepared to find that Professor Seeley advocates a closer affinity between birds and pterodactyls than is usually accorded them. Most anatomists will probably agreee in considering that many features of the skeleton of pterodactyls, such for example as its remarkable pneumaticity are due to modifications for flight, but the author considers that Pterodactyls and Birds form two parallel groups which may be regarded as ancient divergent forks of the same branch of animal life. But whether we accept all Professor Seeley's deductions or not we may safely accept his facts and we are indebted to him for having placed so much information within our reach and for having given it in so readable a form.

'Animals of the Past,' by Frederic A. Lucas, is more popular in its line than 'Dragons of the Air,' and wider in its scope, dealing with a number of the more striking or more interesting of extinct animals and especially with those of gigantic size. Here, however, Mr. Lucas's mission in life appears to be to correct the widespread impression that the animals of the past were so very much larger than those of the present. Some of the dinosaurs we are told were the largest animals that

have walked the face of the earth, but existing whales are the greatest of animals, and the living elephants are larger than the mastodon and compare favorably with the mammoth. The first of the dozen chapters treats of fossils and how they are formed, while the last discusses the problem why do animals become extinct, suggesting some of the causes which lead to extermination, and showing that in some instances apparent extinction is in reality evolution, one species passing into another, so that the race endures while individuals die out; this is well illustrated by the chapter devoted to the ancestry of the horse. Reading the riddles of the rocks tells how animals are interpreted by their fossil remains even if it is not possible to reconstruct an animal from a single bone or tell its size and habits from a tooth. Other chapters are devoted to birds of old, the dinosaurs, feathered giants, the mammoth and the mastodon, and at the end of each chapter is stated where the best examples of the animals described may be seen, while in many instances the size of the largest specimens is given. The book is illustrated with restorations of extinct animals drawn by Mr. C. R. Knight and J. M. Gleeson, and while these may look a little tame beside some of those that have appeared in the Sunday papers, they are the result of long and careful study and may be regarded as among the most accurate that have been made.

ENGINEERING.

A 'Field Manual for Engineers' by Philetus H. Philbrick (Wiley and Sons), treats only of the surveying work of railroad location and construction, but this is set forth in a thorough and interesting manner. No logarithmic tables are given, as is usual in such field-books, the author claiming that 'they are but little used and should not be used at all.' Whatever may be thought of this remarkable statement, it must be said that the twelve pages given on approximate and abridged methods of numerical computations are of great interest and value; if such methods were generally taught to engineering students it would certainly prove highly advantageous in enabling them to perform computations with a degree of precision consistent with the given data.

'Water Filtration Works,' by James H. Fuertes (Wiley and Sons), treats this important topic mainly from the engineering point of view. Both slow filtration by sand beds and rapid filtration by mechanical means with the help of a coagulent are fully described, the methods of clearing and operating being in particular well exemplified by illustrations of the details of plants recently installed. The purification of river waters carrying much suspended matter is discussed in connection with the results of the experiments made at Pittsburgh, Cincinnati and Louisville. For towns where it is doubtful whether a sand filter bed need be covered the author suggests that a combination of the slow and rapid filtering methods might be made, the former being used in summer and the latter in winter. The book bears evidence of having been prepared with care, and it is a valuable addition to the literature of a subject which constantly increases in importance as the public comes more and more to realize that the use of pure water diminishes the death rate from zymotic diseases.

THE PROGRESS OF SCIENCE.

THE CARNEGIE INSTITUTION.

We have the privilege of publishing above the exact words of Mr. Carnegie's trust deed establishing the Carnegie Institution of Washington. The trust has duly been accepted by the trustees, and officers have been elected as follows: Dr. Daniel C. Gilman, president of the institution; Mr. Abram S. Hewitt, chairman of the board of trustees; Dr. John S. Billings, vice-chairman; Dr. Charles D. Walcott, secretary. The executive committee consists of Mr. Abram S. Hewitt, Dr. D. C. Gilman, Secretary Elihu Root, Dr. John S. Billings, Mr. Carroll D. Wright, Dr. S. Weir Mitchell and Dr. Charles D. Walcott. The first regular annual meeting of the board will be held in November next, and in the meanwhile the executive committee will elaborate definite plans for the administration of the institution. It is understood that the advice of scientific men will be requested and that committees of experts will be formed. Part of the income of the trust will be used for the construction of an administration building in Washington. No appropriations will be made before November, but applications may be presented, and these would perhaps be a help rather than a hindrance to the executive committee in formulating their plans. Mr. Carnegie's views as to the scope of the institution and its possible relations to a national university are further outlined in a brief address made to the board of trustees in presenting the deed of gift. He said:

I beg to thank you deeply for so promptly, so cordially, aiding me by acceptance of trusteeship. A note from the president congratulates me upon the 'high character, indeed, I may say, the extraordinarily high character of the trustees'—such are his words. I believe this estimate has been generally approved throughout the wide boundary of the United States.

My first thought was to fulfil the expressed wish of Washington by establishing a university here, but a study of the question forced me to the conclusion that under present conditions were Washington still with us, his finely-balanced judgment would decide that in our generation at least such use of wealth would not be the best.

One of the most serious objections, and one which I could not overcome, was that another university might tend to weaken existing universities. My desire was to cooperate with all educational institutions and establish what would be a source of strength and not of weakness to them, and the idea of a Washington University or of anything of a memorial character was therefore abandoned.

It cost some effort to push aside the tempting idea of a Washington University founded by Andrew Carnegie, which the president of the Woman's George Washington Memorial Association was kind enough to suggest. That may be reserved for another in the future, for the realization of Washington's desire would perhaps justify the linking of another name with his, but certainly nothing else would.

This gift, or the donor, has no pretentions to such honor, and in no wise interferes with the proposed university or with any memorial. It has its own more modest field and is intended to cooperate with all kindred institutions, including the Washington University, if ever built, and it may be built if we continue to increase in population as heretofore for a generation. In this hope I think the name should be sacredly held in reserve. It is not a matter of one million, or ten millions, or even of twenty millions, but of more, to fulfil worthily the wish of Washington, and I think no one would presume to use that almost sacred name except for a university of the very first rank, established by national authority, as he desired. Be it our part in our day and generation to do

what we can to extend the boundaries of human knowledge by utilizing existing institutions.

Gentlemen, your work begins, your aims are high; you seek to extend known forces and to discover and utilize new forces for the benefit of man. Than this there can scarcely be greater work. I wish you abundant success and venture to prophesy that through your efforts in cooperation with those of kindred societies in our country, contributions to the advancement of the race through research, will compare in the near future not unfavorably with those of any other land. Again, I thank you.

SCIENTIFIC WORK HERE AND ABROAD.

Mr. Carnegie expressly states in his trust deed that his chief purpose is 'to secure if possible for the United States of America leadership in the domain of discovery and the utilization of new forces for the benefit of man,' and this function of the institution naturally calls attention to the place now occupied by the United States in the world of science. In the January number of *The North American Review*, Mr. Carl Snyder complains that America is not doing its fair share of scientific work. In a much abler article in the following number of the same review, Professor Simon Newcomb gives more credit to American science, but entitles his article 'Conditions which discourage scientific work in America,' and dwells especially on the lack of appreciation shown by the general public, and especially by legislators, to scientific men and institutions. Other journals have discussed the question, the New York *Independent* remarking: "It must be acknowledged that in original contributions to knowledge the United States is not in the first rank with Germany, France and England, but rather with such countries as Russia, Italy, Sweden and Japan."

We take a more hopeful view of science in America than the authors mentioned. Mr. Snyder, for example, commits the obvious fallacy of comparing the productivity of the United States with that of all other nations combined. We can divide the intellectual world into seven groups not very unequal in population—Germany-Austria, Great Britain and its colonies, France and Belgium, The United States, Italy, Spain and Spanish America, Russia and a miscellaneous group, including Scandinavia, Holland and Japan. The scientific rank of these groups is nearly that of the order in which they are given, but even greater credit should be allowed to the German, French and English, owing to their smaller populations. The United States occupies pretty definitely the middle place, being outclassed by the three great intellectual nations, and surpassing any one of the three groups into which the other nations have been divided. In so far as this is correct, we do approximately our average share of scientific research, about one seventh of the work of the world.

It is quite possible that our contemporary position is somewhat better in work actually being accomplished than in reputation. A scientific man does not usually become eminent until ten or twenty years after his work has been accomplished, and the same would naturally hold for a nation. We are likely to think of Darwin, Pasteur or Helmholtz, and to reproach America for not having produced their equal. But when these men were born and educated the population of the United States was comparatively small, and its intellectual position was admittedly inferior. It is only within the past twenty-five years that true universities have developed in the United States, and positions have been opened that can be occupied by men carrying on scientific research. Those who first availed themselves of these opportunities are only forty or fifty years old, and while they are now doubtless doing their best work, it is not yet recog-

nized outside the ranks of specialists. It is but now that our opportunities for education and research begin to equal those of Germany, and twenty years must be allowed before the harvest can be gathered, and a still longer period before its quality and quantity can be established.

A careful estimate of America's position in the scientific world must consider the different kinds of scientific work. In the applications of science we probably lead. We have had and have great inventors, and in the progress of engineering, manufactures, agriculture, etc., where the individual is often unrecognized, we are contributing more than our share. If further we divide the pure sciences into nine groups—mathematics, astronomy, physics, chemistry, geology, zoology, physiology, botany and anthropology-psychology—the United States would be doing its share if it excelled in one science. We are clearly inferior to several nations in mathematics, physics, chemistry and physiology; we are inferior in reputation, but not obviously so in performance, in zoology, botany and anthropology-psychology; we are probably doing work of greater volume and value than any other nation in astronomy and in geology.

DEMOCRACY AND THE RECOGNITION OF SCIENCE.

Professor Newcomb's article in the February number of the *North American Review* points out how much more highly scientific men and scientific academies are honored abroad than in this country. In the European capitals national leadership of every kind is united in a homogeneous mass. The men of science and of letters associate with the political leaders. Scientific eminence leads to social recognition and political preferment, while those having wealth and leisure engage in scientific research. The national academies are practically parts of the government. In America great endowments are given to universities, but the personality of the professor is ignored; the government makes large appropriations for the scientific bureaus, but scarcely recognizes the National Academy composed of our most eminent scientific men. Professor Newcomb hopes that the Carnegie Institution may attract to Washington men of world-wide reputation and strong personality, who will introduce an academic element into the political atmosphere of the capital.

The extent to which scientific work has been discouraged in America by lack of social recognition is difficult to determine. Greater honor for intellectual distinction might attract young men to a scientific career, whereas worship of wealth may direct too much of the activity of the country to commerce. But the fact that conditions in America differ from those in European nations and that conditions in the twentieth century differ from those in the nineteenth, does not of necessity indicate a retrograde movement. Aristocracies of wealth leisure and culture have undoubtedly been favorable to science, literature and art; but it may be our part to prove that under existing conditions a democracy is still more favorable. The era of the amateur scientist is passing; science must now be advanced by the professional expert. The student of science should be accorded an income commensurate with his services, but the routine of social functions in foreign capitals can scarcely be regarded as favorable to scientific research. Darwin's ill-health and enforced isolation in the country enabled him to do the work he did, whereas social engagements did not improve Huxley's purely scientific work. The lack of a hereditary aristocracy and of a single national social center may not in the end be hurtful to science. If the scientific man is consulted as an expert and his advice is followed, he may be willing to forego invitations to dinner and the patronage of society. Members of the cabinet and

of the congress had formerly more time to cultivate the society of men of science than at present, and perhaps men of science could then also better spare the time. The scientific men under the government are now more highly regarded than ever before. Some years ago they were looked upon as seekers after public patronage and viewed with a certain suspicion. Now they are treated as members of the government, not less essential than officers of the army. In a recent debate in the senate on the organization of a new department of commerce, no senator was able to say to what political party the present head of the bureau of labor belongs, but all agreed that his advice was of special importance in framing the bill. When the government employs skilled experts in all departments, it no longer requires the advice of an academy of sciences. We should like to see the National Academy entrusted with certain definite functions and we should like to see scientific men treated with even greater respect than at present, but on the whole the necessary conditions of a democracy and of an age of specialization do not seem to be unfavorable to scientific work.

WORK OF THE ECLIPSE EXPEDITIONS.

THE director of the Lick Observatory has recently announced that the remarkable coronal disturbance, which was one of the notable features of the Sumatra eclipse, has been found, by Professor Perrine, to be above the prominent and only sunspot visible during eleven days. This interesting discovery emphasizes the fact that results of much value can sometimes be obtained at eclipses, even when the sun is covered by thin clouds. It will be remembered that a total eclipse of the sun occurred on May 17, 1901. The duration of the eclipse was so long, and the possibilities of valuable work so great, that many parties from different countries visited Sumatra, Mauritius, and other islands in the path of totality. Early reports announced that failure was general on account of clouds. Later reports, however, by the directors of the different parties, show that, while many observers accomplished little or nothing, others obtained satisfactory results. Taken altogether the observations are of high value, and will justify the expense incurred. Congress made a generous, if somewhat tardy, appropriation for the observance of this eclipse, and a party was sent out, in charge of Professor A. N. Skinner, embracing six members of the Naval Observatory, and five others. Professor Skinner very wisely decided to divide his party into several divisions. The main party, including himself and Professor Barnard, were stationed at Solok, which seemed to offer the best chance for a clear sky. At the same place were Messrs. Abbott and Draper, of the Smithsonian Institution, and some English astronomers. Little of value was obtained at Solok, owing to clouds. One of the smaller parties, however, at Sawah-Loento, a short distance to the east, had better success. Results of high value were obtained by Dr. Mitchell, of Columbia University, and by Professors Burton and Smith, of the Massachusetts Institute of Technology. Perhaps the only place where a perfectly clear sky was found was at Fort de Kock, and fine photographs were there made by Dr. W. J. Humphreys, of the University of Virginia, and by Mr. G. H. Peters, of the Naval Observatory. The party sent out by the Lick Observatory, in charge of Professor Perrine, was stationed at Padang. Throughout the totality thin clouds covered the sun. These clouds undoubtedly interfered with some of the photographic results, especially those which were concerned with the search for an intra-mercurial planet. But the polariscopic and spectroscopic results, as well as the photographs of the inner and middle corona appeared to be only slightly affected by the clouds. The

Amherst College party in charge of Professor Todd was at Singkep, where the sky was very unfavorable. At Mauritius the English astronomers had a fair sky. This eclipse well illustrates the importance of a large number of stations scattered along the belt of totality, for in spite of the clouds which widely prevailed the results from the stations, as a whole, are very satisfactory and will encourage similar efforts at coming eclipses.

THE SPECTRUM OF LIGHTNING.

Very wide interest has been taken in the spectrum of lightning, photographs of which have been obtained at the Harvard College Observatory. These were made by pointing a telescope, provided with an objective prism toward a portion of the sky where lightning was particularly bright. The spectrum is not always the same. Many of the lines appear to be due to hydrogen. The first line is a broad, bright band, extending from wave-length 3,830 to 3,930, and may be identical with the nebular line 3,875. The spectrum of lightning is curiously like that of the new star in Perseus, and other new stars. Now that the method of obtaining such photographs has been shown, it would seem possible to obtain a large number of them, taken under different conditions for a more complete study of the subject.

THE MANUFACTURE OF SULFURIC ACID.

Of all the products of chemical industry, sulfuric acid has always held the first place, and its importance increases yearly, since there is hardly a branch of manufacture in which it is not largely used. Its manufacture by the lead-chamber process has been universal until within a few years. This requires a large plant and the acid obtained is dilute. For many purposes this must be concentrated at no inconsiderable expense. Vessels of platinum are very generally used and a single still may cost upwards of $10,000. With the development of the coal-tar industry in Germany, and especially in connection with the rapidly increasing manufacture of artificial indigo, has come a demand for the more concentrated acid in large quantities.

That under the catalytic action of finely divided platinum, sulfur dioxid can be burned to sulfur trioxid, which with water gives sulfuric acid, has been known for nearly three quarters of a century, and in 1831 a patent was secured in England for the manufacture of the acid by this process. But in spite of vast amounts of effort devoted to it, and by some of the world's most distinguished chemists, this has never been made a practical success. Under the stimulus of the demand of the color factories of Germany, this problem has been very actively attacked in the past few years by their chemists, and at last the efforts have been crowned with the desired reward.

This work has been chiefly carried on under the auspices of the Badischen Anilin- und Soda Fabrik at Ludwigshafen. Theoretically the process is a model of simplicity. The gases from the pyrites burners, consisting chiefly of sulfur dioxid, oxygen and nitrogen from the air used, are, after purification and cooling, led through cylinders containing plates on which a contact mixture, with platinum as one of its constituents, is placed. The sulfur dioxid burns with the oxygen present in the gas, giving the trioxid, which is absorbed in a dilute acid. The acid obtained may be pure sulfuric acid, or may contain an excess of the trioxid—the fuming or Nordhausen acid. Several years of most patient investigation were, however, required before the conditions were discovered by which the process could be kept in continuous operation, there being a great tendency for the platinum mixture to cease its work after a few days' or even hours' use. This was due to the presence of

impurities in the gas from the burners and especially to arsenic. The slightest trace of this element at once inhibits the action of the platinum.

The success of this process has not only introduced a competitor which must eventually very much restrict the use of lead chambers, but one which possesses two important advantages, one in that it is more economical to manufacture a strong acid at once, thus doing away with concentration plants, and the other that it furnishes an acid which is free from arsenic. This may well be considered the greatest triumph of technical chemistry in the last decade.

SCIENTIFIC ITEMS.

Dr. Nicholas Murray Butler, professor of philosophy and education, and since the resignation of Dr. Seth Low acting-president of Columbia University, was elected president of the University on January 6 by unanimous vote of the trustees. The ceremonies of installation will take place on April 19.

Johns Hopkins University celebrated on February 21 and 22 its twenty-fifth anniversary, when President Remsen was formally installed. Dr. D. C. Gilman, president emeritus, delivered the commemorative address on the afternoon of February 21. President Remsen made his inaugural address on February 22.

'The Races of Europe,' originally published as a series of articles in this magazine, by Professor W. Z. Ripley, of the Massachusetts Institute of Technology, and professor-elect of economics at Harvard University, has been 'crowned' by the award of the prix Bertillon of the Société d' Anthropologie of Paris.—Professor J. W. Gregory has been appointed acting head of the Geological Survey of Victoria, with a view to its reorganization.—Dr. Eugen Warming has been appointed director of the Geological Survey of Denmark. —At the meeting of the Paris Academy of Sciences on January 6, M. Bouquet de la Grye, the engineer, succeeded to the presidency.

Mr. Andrew Carnegie and the descendants of Peter Cooper have respectively given $300,000 to Cooper Union, New York City, doubling the gifts made by them to the Union three years ago. —Mr. and Mrs. Harold S. McCormick, of Chicago, have founded a memorial institute for infectious diseases to commemorate their son who died recently from scarlet fever. The endowment of the institute is said to be $1,000,000. Dr. Frank Billings is president of the board of trustees and Dr. Ludvig Hektoen has been appointed director of the institute.—The Laboratory of Engineering, presented to the Stevens Institute of Technology by Mr. Andrew Carnegie, at a cost of $55,000, was dedicated on February 6.—The British National Physical Laboratory at Bushy House will be officially opened on March 19.

Dr. W. A. Herdman, F.R.S., professor of zoology at University College, Liverpool, sailed for Ceylon on December 26, 1901, to undertake for the government an investigation of the pearl oyster fisheries of the Gulf of Manaar. —Professor Ralph S. Tarr, of Cornell University, is spending the winter in geological study in Italy and will spend the spring and summer in the study of the glacial deposits of Germany and the British Isles.—Professor C. H. Eigenmann has leave of absence during March, and will visit some of the caves of western Cuba to secure a series of the cave fauna.

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IS THIS A DEGENERATE AGE?

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TOO many writers and speakers, in discussing the intellectual and social conditions of our time, find little of good and a superabundance of bad. Everywhere they discover evidence of individual and social degeneracy. The love of literature and of pure science is disappearing; college training is debased in that the purely intellectual side is neglected for the practical; everything is dominated by an intense commercialism, which destroys men's finer instincts and lowers the general moral tone of the community.

One may not ignore these utterances; nor may he dismiss them flippantly as wailings of disappointed or unsuccessful men, who would make a virtue of necessity. Men's goals may differ, but their ambition is the same; it ill becomes one to scoff at another; scoffing is bred of ignorance as much in the fortune-chaser who ridicules the student as in the student who contemns the man with the muckrake. The indictment against our age has been drawn by men, who, from their standpoint, have been successful and have no grievance against the world. Many of them belong to the class which, for a long period, dominated thought and controlled the policy of nations. Their statements deserve such careful consideration that one does well to inquire whether or not the conditions are as represented and to what extent they are evidence of either intellectual or social degeneracy. The subject is a broad one and, in treating it, one may adopt only the rambling method of the essay, that he may move hither and yon as necessity may dictate.

Prior to the Civil War, our colleges, modeled for the most part

upon German gymnasia, offered such mental training as was supposed to be prerequisite for professional study. But new conditions arose with the close of that war—the country had discovered its mineral wealth and had accumulated capital for development; the world had learned of America, and its surplus population poured in upon us, ignorant of our laws, alien to our modes of thought, yet eligible to citizenship, to a voice in our government. At once, the demand arose for an education adapted to the needs of those who did not intend to become lawyers, clergymen or physicians, who required a broader, stronger training, fitting men to cope with the new difficulties and to solve the new problems.

It is true that, long before the Civil War, many eminent men had recognized the inherent defects in our college system. They asserted that training in classical languages should not be the important feature of college education; that the Roman church no longer controlled thought or education and that Latin had ceased to be the language of learned men, while changed conditions in professional study had rendered thorough knowledge of Greek equally unessential, so that those languages should be replaced by others as necessary now as those had been. The colleges themselves had recognized the transition and Latin and Greek were taught, with few exceptions, not with a view to impart knowledge of the tongues but with a view to mental training. In other words, Latin and Greek were employed for mental exercise as Indian clubs are employed for muscular exercise in a gymnasium. But no material change was made in curricula; natural science was introduced, but was taught in a most elementary way, while the most precious years of a lad's life were spent as before in monotonous study of paradigms and syntax.

The abrupt demand for better education found our colleges unprepared to meet it. The faculties were composed for the most part of men trained after the accepted method, students by habit, living in a cosmos of their own and conceiving of the outer world very largely as they constructed it on *à priori* principles. As they knew practically nothing about the conditions which made a radical change necessary, the demand was like a rude awakening. Makeshifts were offered as tubs thrown to a whale; subjects dealing with everyday life were introduced into the 'regular' course and the student was led to think in a somewhat 'lower intellectual plane,' that is to say, more nearly in accordance with the actual condition of things. Under the old system he was in the nineteenth century world, but very truly not of it; under the modified system, he was permitted, during part of the college hours, to be actually in touch with it; facts were dealt with sometimes in political economy, a bit of physiology found its way into psychology, the chemistry of common things became a legitimate subject of dis-

cussion. So-called scientific courses were added in many cases, but usually they were so ill-adjusted as to be laughing-stocks for those taking the formal courses.

But mere makeshifts could not suffice; the country's material development was advancing rapidly but not always profitably. Competent men were too few; the successful pit-boss was a poor mining superintendent amid novel conditions; the land-surveyor was helpless in a new region; the iron-founder of high repute proved himself a hopeless blunderer when tried on strange ores and furnaces. The successful men were those who had been trained in the American technical schools or in those of Germany. Their success marked out the line of needed preparation and emphasized the demand for men broadly educated in principles as well as in practical applications of science. Schools were established and courses planned to meet the requirements. The number of scientific and technical students increased rapidly, and, in not a few institutions, soon exceeded, as it does still, that of students adhering to older so-called literary courses. Certainly this condition affords good ground for the complaint respecting college education.

Yet not so. The desertion of the, so to speak, unapplied side is apparent, not real. There is no such desertion. Unquestionably, of the students now in American colleges and high schools, the percentage taking modified courses of the older type is much smaller than it was forty years ago; but that is not the proper percentage for use in comparison. Not relation to the total number of students but relation to the total population is the basis for comparison. From this standpoint one sees that the proportion adhering to the unapplied side has increased more rapidly than the population—indeed, one may make a greater restriction and say that the number of those taking classical courses has increased out of proportion to the population. There has been no decrease, on the contrary there has been an increase, of interest in literary study, while, on the other hand, thousands are acquiring mental training and much of mental culture by pursuing difficult courses almost unknown to our colleges of forty years ago. Formerly, the majority of college men had professional life in view; now it is 'the thing' to have a college degree, without reference to one's intended calling.

But this avails nothing. The proof of the pudding is in the eating; and we are told that no great poet now lives among English-speaking peoples and that in our country no eminent writer has arisen within two decades—this, because 'every man's mind is turned to material things.' Recently our patriotic pride was wounded by the announcement that America has produced no Shakespeare, no Newton, no Copernicus, no men of some other kinds—and this, too, because of our devotion to gross things. One may remark here, parenthetically, that

when we consider that, in all the centuries of English-speaking times, the race has produced only one Shakespeare, the condition is not so saddening as it might be; the less so, since in our own day our country has produced a Newcomb in mathematics, a Rowland in physics and others in other branches of pure science, each of whom deserves a niche, not far, at least, from that of Newton. Were Newton living in the United States to-day he would have no lonely preeminence, he would be but one of a galaxy. A later writer tells us that now, instead of the fires of the creative imagination, we have the fires of the mogul engine —that we cannot have both at the same time.

The creative imagination in the limited literary sense was most unfettered amid primitive conditions, when rhapsodists such as the authors of Homer, the Sagas or the Kalevala chanted the exploits of gods or heroes. As men's experience widened, as their concepts increased in number, as their thought became philosophic, the product of imagination changed in form as well as in character until it dealt not with environments familiar alike to man and beast, but with broad principles. The poem in simple form, possibly the most beautiful form, appeals to the childlike side of our nature. Great poetical works, such as those of Shakespeare and Milton, appeal to us not because of their poetic form, not so much because of their imagery as because of the subtle philosophy which pervades them. Milton appealed to very few in his own day as a poet; he appeals to not many more in our day. Shakespeare's wit has been equaled by later dramatists; his constructive skill has been excelled by some; but his critical insight into human nature remains without rival. The Shakespeares and Miltons of our day write in prose.

Works such as those of Shakespeare and Milton would be an anachronism in our day. Men read carefully, thoughtfully; they think quickly and, as compared with earlier times, accurately. Arguments clothed with rhetorical figures have little power—one has not time in which to scrape off tinsel in order to reach the substance. Reading matter must be trivial or serious; if trivial, thoroughly so, that it may while away hours of weariness; if serious, it must be deserving of study; working hours are too few to be wasted on that which brings no reward. Here one finds reason for the remarkable sale of ephemeral works as well as for the equally remarkable sale of important works. There could be no better evidence of the intellectual growth in our day, a growth not confined to the more favored classes, but characterizing all from the richest to the poorest. Doctrinaires may sneer at the reading propensities of the working classes and may assert that little good can come from reading the stuff which they choose. Others recognize gratefully that the novels now read by such people are better morally and intellectually than those which served as mental food for the more

favored classes of a century ago. The vastly increased number of students in our colleges and high schools is but the natural outcome of this intellectual growth.

Unfortunately, this condition gives room for apprehension; the increase in number of students is said to be so far out of proportion to the population that there is danger of over-education; the professions will be overcrowded with ill-paid workers, who might have gained a comfortable living in other callings. This foreboding is not new; it was old a century ago and was as true then as it is now. Many good men, mistaking their vocation, have gone into professions, though fitted by nature to be only hewers of wood and drawers of water, while others have wasted their lives in professional work, who would have been successful as merchants. There is no danger that the condition will be worse because of increased facility for acquiring an education.

If higher education were merely preparation for service in the so-called learned professions of law, medicine and theology, there might be room for anxiety. But higher education has no longer an aim so narrow as that—it is not to meet the needs of the few, it is to fit the many for life's work. Fifty years ago, college life certainly tended to unfit men for the sterner realities of life, for the whole course of training was as far removed as possible from relation to the ordinary conditions; but not so to-day. For the most part, college professors are no longer recluses; they are expected to take part in social movements; even in politics; many of them, especially of those on the scientific side, are interested in vast business enterprises, partly because they gain greater opportunity for investigation and partly because, as investigators, they need incomes greater than the meager salaries paid by colleges. Training by such men is very different from that by closet students.

All this is conceded, but only that one may make more strongly the assertion that everything looks to the practical, that real culture is neglected, that we are living on the literature of an earlier generation, for nothing new is produced. The difficulty lies in the vagueness of the terms 'culture' and 'literature.' The writer has made diligent search among college men for a clean-cut definition of 'culture.' The results are not wholly satisfactory. Among professors, there is a tendency to regard culture as that mental condition attained through close application to the studies embraced within the definer's department; some in professional life appear to think that it is a something acquired only by close application to such studies as have no practical application; they are inclined to deny the title of culture study to modern languages; had they lived a century and a half ago, doubtless they would have denied that title to the ancient languages, which at that time were studied solely with a view to use; a great majority of the older college graduates maintain that it is that peculiar mental

polish derived from pursuit of the old classical course, and regard themselves as examples—a comfortable frame of mind, truly. Evidently mental culture and mental refinement are synonymous terms to most of those who use the former term, but this is not sufficient; mere refinement must not be all, there must be strength in addition. The all-important culture studies are those which make also for robustness, which enable a man to see broadly, to make inductions safely and to tell to others clearly what he wishes to communicate. Such studies are taught now as never before and with them are taught, also as never before, other studies which make mostly for refinement. A boy entering college to-day must have better acquaintance with history and English literature than had seniors in most of our colleges fifty years ago. Long steps have been taken by several of our States toward making law and medicine actually, instead of nominally, learned professions. Men must have some education before entering upon professional study.

Similarly, the significance of 'literature' must be made definite; it changes with the times. Medieval literature consisted almost wholly of treatises upon harmless topics—such as involved no danger of dispute with church authorities; after the revival of learning, literature was based chiefly upon the newly revealed classics of Greece and Rome; still later, historical disquisitions and philosophical discussions in various forms made up the mass—in each period, that mass concerned matters then most widely interesting. The survivors of each preceding period must have chanted jeremiads over the intellectual decline. In our age, those who love the poem, the essay, the drama, the polished novel and philosophical history, written with a purpose, do find themselves lost. They cannot see good in the development of a new literature, embracing philosophy, archeology, sociology, the natural sciences—a strong literature, often as polished as the old, and showing on the whole a virility unknown even fifty years ago. It reflects the spirit of the age, it is truthful, accurate, honest.

And this brings us to the essence of the whole matter. Stripped of all incidentals, the assertion is that, neglecting mental culture, we have been led to neglect man's higher interests; we have fallen into a slough where everything is subordinated to gain and the rights of man are not regarded; a grasping selfishness brings about combinations in manufacturing interests and makes possible the accumulation of vast fortunes; a base 'commercialism' pervades all society; the body politic is corrupt and honesty has well-nigh disappeared.

The charge that mental culture has been neglected has been considered; it is not true. The other charges remain.

For one hundred years the civilized world has been undergoing repeated transitions. At the beginning of the nineteenth century men lived in quiet; there was no haste. With unfavorable wind, a sloop

might require five days instead of two for the voyage from Albany to New York, just as a vessel, under similar conditions, thirty years later, might be six or seven weeks on the way from London to New York; but the delay caused little more of irritation among the passengers than would be caused to-day if the Empire Express were two hours late. Even sixty years ago, a journey to St. Louis was an undertaking equal to that of crossing the ocean; in each case, the expectant traveler made his will and his friends assembled to bid a sorrowful farewell. Now one makes less preparation for a tour around the globe. Sixty years ago, mails were irregular and postage was from ten to twenty times what it is now. The arrival of a stranger in a village was an event; he brought information from the outer world. The man who had been one thousand miles from home, received more consideration in a large town than is granted in a petty hamlet to a full-developed globe-trotter. Even sixty years ago, forges or petty furnaces, scattered about the country supplied the necessities of the community.

But steamboats, railways and telegraphs brought all parts of the land into actual contact; the discovery of petroleum and the cheapening of kerosene by improved methods of refining carried light into the most secluded corners, and added several hours of life to each day among farming communities; the vast expansion of manufactures during the Civil War led to modifications in educational methods, which in their turn made possible the utilization of our mineral resources. Each advance made others imperative. The repertoire of discoveries in physical science was ransacked in search of those which could be utilized by inventors; every discovery, every invention was welcomed and tested.

Improvements followed in such rapid succession that one, in reviewing the last thirty years, becomes confused and the movements appear as irregular and unrelated as those in a quickly-revolving kaleidoscope. The age of Holley-Mushet-Bessemer steel burst upon us and revolutionized not merely our railroad systems but also our ship-building and architecture. Henry's telegraph, introduced by Morse's energy and Vail's receiver, was spread as a network over the whole country; the researches of Helmholtz and Lissajou led up to Bell's telephone; Faraday's discovery grew into the dynamo, which introduced the age of electricity.

But these changes made more of life, thrust more into life so that more was required of life. The transition or rather the series of transitions was severe. It is the commonplace of history that no great advance is made, except, for the time, at the expense of human life or comfort. Steamships have driven from the sea fleets of vessels and have made the sailor almost a thing of the past; railroads destroyed the prosperity of communities bordering the great turnpikes crossing Maryland, Pennsylvania, Ohio and Indiana, and compelled abandon-

ment of the furnaces whose ruins have been described as picturesque additions to Pennsylvania's scenery. The sewing-machine caused untold misery, as did the power-loom, the shoe-machine and other inventions, which the world now regards as unmixed blessings.

Progress in manufactures, combined with increasing ease of communication and transportation, made the business world more compact and intensified competition. The struggle for existence led to frequent changes in method, at once destructive and constructive. In iron manufacture, small furnaces soon brought only loss to their owners; in trade, the small shopkeeper, who idled for half the day waiting for chance customers, found himself neglected. The story was alike for all. The owner of the petty furnace, like the keeper of the petty shop, was displaced by his more energetic rival, who recognized the coming change and so arranged that by smaller percentage profits on greater sales he might secure increased profit on his business capital. Men may groan in bitterness of spirit as they please, they may denounce the avarice of a manufacturer who sees fit to make the iron and to convert it into the finished product, all within one plant; or that of the merchant, who chooses to sell dry goods, shoes, groceries and hardware on a great scale under one roof; they may denounce, if they will, the man who, having gained the advantage over his less energetic neighbors, strives to prevent another from depriving him of it—the denouncing amounts to nothing. The condition is normal to the advance of the race, for, while bringing disaster to the few, it brings increasing comfort to the many. The energetic man, other things being equal, wins in the race for money, fame, usefulness; in this world every man receives practically full pay for the net average of his abilities. This is nature's law; no legislation avails for its repeal.

This is not the place to discuss the propriety of placing limitations upon combinations of manufacturing interests; the wisdom of permitting the accumulation of vast fortunes; the justice of permitting such fortunes to be inherited so as to support descendants in idleness or dissipation. Such questions are irrelevant in this connection, for we have merely to ascertain whether or not the commercial development of the last half-century has led to a lowering of the moral tone and to the injury of mankind.

Just here one may halt. The term 'commercialism,' like 'culture,' is so vague, so comprehensive as to be elusive. It certainly is serviceable. If a man fail to secure funds for some object dear to him, the failure is not due to any deficiency on his part or even to the nature of the project, but only to 'commercialism.' In such cases, the term is usually synonymous with common sense.

But in a broader way, the term refers to a supposed general deterioration of personal honor, due to the commercial life of our com-

munity. As the whole commercial system is based upon buying and selling, men have come to regard all things as fairly objects for barter and to look upon honor as something transcendental. This conception, the foundation for so many pessimistic forebodings, reflects no credit upon the knowledge or good sense of those who accept it and it may be dismissed as purely *à priori*. There never was a time when business honor was so high as now; the whole commercial fabric is based upon it. Whether the moral sense has been quickened or experience has taught that honesty is the best policy, matters not—the fact remains that in business a man must be honest and honorable; dishonest dealing is fatal. Dishonesty certainly exists as it always has existed and as it always will exist until man's nature changes. It is no novelty, for long ago it was asserted that every man has his price. But there is proportionately less now than ever before.

If 'commercialism' be that which destroys man's better part and makes him ready to subordinate everything to success in his ventures, which induces a soulless indifference to the welfare and even rights of neighbors, competitors and employees, surely we have here no nineteenth century disease over whose discovery so great ado should be made. If perverted ambition, selfishness, lack of principle and indifference to the rights of others be what is meant by 'commercialism,' we have but a new name for that which is as old and as widespread as the human race. It is the same thing, whether in the merchant's counting room or in the clergyman's study. When Napoleon asked contemptuously 'What are the lives of a thousand men to me?' his spirit was the same as that of an oppressive employer; the efforts made by the great 'trusts' of to-day to overcome competition differ in no wise from the cutting of prices between cross-road stores of fifty years ago, or the tricky manipulation of ecclesiastical councils in Constantine's time—or even later.

Inordinate anxiety for wealth and for the power which its possessor can wield is not peculiar to the commercialism of our time. It was quite as inordinate in the quiet days of one hundred years ago as in the golden days of Rome. It has always led to oppression and it has always contaminated society and politics. The satirists of Rome inveighed against its evils as bitterly as do the moralists of our day; the Israelites knew the burden long enough before Solomon's day to make proverbs respecting it; it led the Assyrians along many a bloody path in western Asia; the patrician of ancient Italy lusted for gold as earnestly as did the merchant and in modern Italy one can find no distinction in this respect between the noble and the contemned 'commerciante.' Avarice corrupted politics in the golden age of Rome and in the Elizabethan age of England as thoroughly as during the Second Empire of France or during the Croker Empire in commercial New

York. The conditions which some would have us believe due to commercialism are but manifestations of man's fundamental belief that might makes right.

In this twentieth century, when the peoples of this world are no longer isolated communities, when bonds of steel bind all together, when through causes determined in long past geological ages some nations are agricultural, others manufacturing and others still confined to mining, so that all are mutually dependent, modes of thought and expression, proper enough in medieval times, are no longer wise, are truly anachronisms. One exhibits no evidence of knowledge or of good judgment who asserts that a professional life is of necessity purer, truer or loftier in aim than a life devoted to commercial pursuits. It is not long, in human history, since the only honorable profession was that of arms—thence to theology, law and medicine was a far reach and that to commerce still further. Then each caste, like Sophomores in college, avenged its injuries on that below. But that day has passed, never to return, and thoughtful men everywhere recognize that, in all callings alike, success depends on intellectual power of much the same type, and that the old-time distinction between professional and non-professional men exists in name rather than in fact.

Ours is an age of commerce, an age of devotion to material things; but that devotion has none of grossness nor is it in any sense inconsistent with a just devotion to higher things. Thus far, the argument has been largely negative, an effort to show that this age is not worse, but possibly better than its predecessors. The positive argument remains, to show that, because of commercialism, this age on the whole is vastly better than its predecessors.

The twentieth century opens with the establishment of a Permanent Court of International Arbitration, for which the world is indebted to the great commercial nations. The Hague conference was called by the Emperor of Russia, a nation not usually regarded as commercial, but that conference was due primarily to the course of Great Britain and the United States, which had tested arbitration and, by submitting to awards, not always just, had set the example for other nations. Peace between nations depends no longer merely upon armies and navies. War is no longer a matter affecting only the internal affairs of the nations directly involved; it concerns all, for commercial bonds unite all. Divine right of kingly authority is becoming an abstraction; the king bows to his subject and restrains his greed for conquest when bankers refuse to finance his loans. The exigencies of commerce have aroused a public opinion which curbs rapacity and demands arbitration of international disputes. War between Great Britain and the United States is well-nigh impossible—it would lead to financial ruin in both countries. The terrible conflict between Slav and Teuton, for which

so many wait in dread, is likely to remain a nightmare. Great Britain needs Russia's grain; Russia needs the manufactures of Britain and Germany. Germans control Russia's trade even in far-off Siberia, and Germans are teaching Russians how to develop their resources. The rabble in each country may rave as they please—a power mightier than they makes for peace.

The same influence is exerted for maintenance of friendly relations within the commercial nations themselves. Compulsory arbitration of labor disputes has been established in some portions of the British empire and several of our own states have taken the initial step by appointing arbitration commissions to serve when called upon. The trend of public opinion among us was shown during the recent steel strike, when arbitration was urged not only by journals defending the strikers but also by those which denounced the strike as wholly unjustifiable. Individual differences, settled in olden time by combat, are settled now by arbitration before judge or jury in open court; the day is not far distant when differences between organizations, large and small, will be settled in the same way. Here, too, our vast commercial organizations make for peace, since their gigantic interests are so interwoven with the equally gigantic interests of labor that serious interruption of friendly relations threatens destruction to both.

Improvement in politics is not very distinct to those living in our great cities, for the present degradation is of comparatively recent origin and due largely to foreign immigration. Cities, like sieves, permit most of the good to pass through and the worthless to remain, while universal suffrage enables this residuum to convert them into sinks, which receive partial cleansing only when rogues disagree and the 'outs' seek revenge by temporary combination with decent people. Leaving the cities out of consideration as temporary anomalies, one finds that men holding positions of honor and trust are expected to perform their duties faithfully. Charges of corruption are not bandied about freely by reputable journals as they were sixty years ago; in Great Britain and the United States, errors in policy are not charged to venality, but to lack of common sense. Fair dealing is so ingrained in commercial life that we are coming to expect it naturally in political life. 'Senator Sorghum,' the creation of a jester, belongs so much to the past that his utterances afford only amusement. Commercial Britain has the best city governments in the world; its civil and diplomatic service shows a sense of honor as high as that of the American army; within the United States, civil service reform has gone far toward removing the evils of patronage which degraded our politics even less than thirty years ago. It is true that politics here and in Great Britain are far removed from millennial conditions, but another

half-century of equal advance would bring them very near to the ideal condition.

The American employer discovered, long before the missionary, that the condition of a man's body has much to do with his openness to reason. Men, well-fed, well-clad and comfortably housed, are more efficient in every respect than are men scantily supplied and embittered against the dealings of Providence. The recognition of this fact—the recognition of manhood in the employee—is the basis of American commercialism, the true secret of its success. This recognition is less marked in Great Britain, where all are bound by traditions from which men free themselves slowly and with difficulty, but the keenness of American competition is compelling the recognition. In our land, mere animal strength counts for little in man, machinery takes its place; the steam shovel has displaced thousands of hands, but it has made necessary an immense number of intelligent men; our rolling mills are no longer crowded with an army of laborers, dull, sluggish, automatic; the work is done by a, so to speak, handful of men, keen-eyed and alert. Of course, this recognition may be due to no altruism on the employer's part, but that is wholly aside from the issue—we are considering conditions, not motives.

Increased wages came with increased value of service—whether through the employer's wisdom or through compulsion, matters not. Decreased cost of living came with increased wages, for, owing to the introduction of machinery, wages did not keep pace with capacity for production. The condition of the mechanic in respect of food, lodgings and general surroundings has shown steady improvement during the last thirty years. In the United States, food is cheap and abundant; the homes of our laboring classes are better than anywhere else. Away from towns, owners of mines or great manufacturing establishments, knowing that men, to do good work, must be well cared for, build comfortable homes for their employees and charge low rental. Many of them recognize a certain responsibility; they encourage thrift and urge, even assist, employees to own their dwellings. Mr. Carnegie is not the single instance of this type of employer, as many suppose. He was one of the first to develop the plan, but many have followed in his steps. Even in New York city, where the tenement problem is so complicated, owing to the form of Manhattan Island, the accommodations for those with mechanics' wages are inviting, while the wretched conditions in the Italian quarter are, to say the least, an improvement upon those in Naples.

This recognition of those, who in non-commercial countries are regarded as the 'mudsills of society,'—to use the language of an ante-bellum senator from North Carolina—has had a reflex influence upon those living amid more favorable surroundings. One hundred years

ago any hovel answered for the poor man, while the rich neglected what, in our day, are called ordinary sanitary precautions. Now a board of health is an essential part of city government and it has powers which, in other departments, would be regarded as despotic. Problems of ventilation, space of living apartments, sewage disposal and street cleaning are those for the sanitary engineer, whose profession is dignified and requires years of preparation. The hydraulic engineer no longer expends his chief efforts upon quays, harbor walls or dams; those are still important, but far more important are problems relating to water-supply for cities, towns and even small villages. Nothing bearing upon public health is too insignificant for notice; neglect by a traction company to provide closed cars on a cool day awakes editors to write indignantly. Sanitary regulations have led to sanitary living, so that, in spite of the fact that men work more intensely than ever before, they break down less rapidly and fourscore is more nearly man's expectation of life now than was threescore and ten fifty years ago.

The rights of man as man before the law are acknowledged by the two great commercial nations as never before and as by no other nations. A defendant no longer rests under the assumption of guilt; he is innocent until the charge has been proved; a married woman is no longer merged in her husband; in the eye of the law, she is at least her husband's equal. The poor man and his wealthy neighbor stand on a common level in the court room and at the polls. Taxes are distributed justly and the rich, as well as the less favored, bear an equitable share of the governmental burdens.

Having granted universal suffrage, the two great commercial nations have been compelled to recognize man's intellectual needs. They offer opportunity for education to all, even straining the prerogative of government to do so. Education, free from ecclesiastical control, is no longer a privilege obtainable only by purchase, it is the right of every man. More, it is maintained that government is bound not only to offer the opportunity, but also to compel its acceptance. The poorest man has the way open in our land from the primary school to the close of professional preparation, practically without cost. Machiavelli has grouped the people of any nation into three classes—those who think for themselves, always few in number; those who think as others think, the intelligent middle class; those who do not think, the great mass of the population. His grouping is still applicable to Great Britain and the United States, but our schools, our sharp political contests and the wide circulation of journals have led to great changes in the relative proportions of the classes. The growth of liberal parties and the increasing independent vote, with which politicians have to reckon, are manifestations of the change.

Commercialism, leading to such broad results for all, has a marked influence upon those who have led in the advance. American men of commerce, be they lawyers, merchants, manufacturers, bankers or railroad managers, acknowledge the community of interest and seek fame or immortality as philanthropists. They cherish hospitals, they endeavor to improve the condition of the poor, they found universities, they endow public libraries, they establish vast museums. A Howard, a Shaftesbury was a strange phenomenon. There are many Howards and Shaftesburys in our great cities, who, having acquired or inherited great wealth, spend their hours not in selfish indulgence but in devoted efforts to make the world better and happier.

One cannot ignore the fact there are many, whose only enjoyment apparently is found in flaunting their wealth in the face of the poor, but they are no longer objects of admiration on the one hand or of fear on the other; the community looks upon them with mingled pity and contempt. Selfish employers are not unknown, oppression has not ceased, poverty, suffering and crime are on every side; in many respects, the evil more than counterbalances the good; all this we know; but we know also that, in all that makes for good, the condition in the two great commercial nations to-day is far, far beyond that existing in the golden age of Rome or Greece or in the Elizabethan age of England. The very anxiety to relieve the oppressed makes us familiar with the prevailing sorrow and leads those, who under former conditions would have been ignorant or unobserving, to their gloomy pessimism respecting the future.

As for the fires of creative imagination, one may say only that they are as brilliant now as at any previous time—with this difference, creative imagination is about better business now than formerly—it no longer wastes itself in cultivating merely the esthetic side of man, it works for his uplifting, physically, morally, intellectually.

THE FORMATION AND MOTIONS OF CLOUDS.

By Professor FRANK H. BIGELOW,
U. S. WEATHER BUREAU.

THE most beautiful objects in the sky are clouds, and their daily procession from west to east in northern latitudes forms a moving tableau of living pictures for those who have eyes to see. The glories of the sunrise and sunset, decking the fading stars of the morning and the waxing lights of the evening with the pure colors of the spectrum, elevate the heart of man to a loftier adoration for the marvels of nature, than any works of art prepared by his own hand. The exquisite tints of the twilight in the northern, and the even richer tones of the tropic zones, are painted on the memories of those who have crossed the equator. I have seen on the Island of Ascension a set of spectrum bows spread over the evening clouds, as if several rainbows had conspired to illuminate the heavens at the same moment. There are possibly two or three other objects in the sky that rival or even excel these cloud pictures in delicacy of light and shading. They are the aurora with its quivering beams dancing in the cool atmosphere of the polar night, and the star clusters of the nebulae in the milky way near the Southern Cross, viewed through the great refractors of the south.

Such effects are produced by the prismatic action of the small spheres of condensed aqueous vapor that make up the cloud. The rays from the sun, when it is near the horizon, pass through these crystal spherules at such angles that the emergent light is spread out in numerous spectra. The white light coming from space is singly and doubly reflected and refracted within the surface of each aqueous globule, so as to become separated into the bands of color which correspond to the wave-lengths of the solar radiations. The rainbow is a typical illustration of this process, but an illuminated cloudlet represents a million minute bows intersecting each other in all possible directions. The colored clouds of the morning and evening are bright because the light from the sun passes at proper angles to the cloud, and from the cloud to the observer, through a given thickness of the vapor, till the refracted rays are brought down to the earth. The midday clouds are white and glistening, because the sun's rays pass through them as scattered instead of as refracted light, dancing from drop to drop in zigzag courses till the last reflection brings it down to the eye of the observer.

The formation of the vapor drops that make the cloud was long a puzzle to science, but modern research has at last succeeded in solving this mystery. It has been found by experiments that if pure dry air, and pure vapor of water, be mixed in a clean vessel, and then cooled down below the temperature of saturation, the drops of mist are not generally able to form. Purity means that all the particles of dust which float in the air have been perfectly filtered out, and that all traces of electricity have been removed from the air and the vapor before mixing them. It was further discovered that if fine dust powder is injected into the pure mixture, without changing the temperature or the pressure, the drops of water developed at once; also that if minute charges of electricity, carried on particles of matter which may be as small as one-thousandth part of the mass of an atom of hydrogen, are introduced, the drops are able to condense. It is inferred that nuclei of some kind, dust particles or electric particles, called ions or electrons, are required for the formation of water drops suspended in dry air, one nucleus for each drop. Hence, it is possible by counting the number of minute drops that form in a cubic inch, to estimate the number of motes of dust in the air, and even the number of ions charged with electricity in a given volume. The number of the ions contained in the air may be enormous, ranging from 20 per cubic centimeter to many millions. We perceive further that these minute drops coalesce to form rain, which falls from the clouds to the ground, and that they carry down the dust previously blown up by the winds and so purify the atmosphere from all sorts of small floating particles. They also bring electric charges to the earth, and this has something to do with producing the atmospheric electrical potential which always exists. These ions are a natural portion of the atmosphere itself, being continuously produced in it, even when no special cause seems to be present, and they have much to do with explaining some of the strange characteristics of atmospheric electricity which have so long baffled all efforts to comprehend. Investigators are now paying the closest attention to these ions from every point of view.

After clouds have been formed by the condensation of the aqueous vapor, which has been lifted by evaporation from the surface of water at the earth into the air, they take on very different shapes according to circumstances. They may be broadly divided into two classes, the cumulus type and the stratus type. Cumulus clouds are the fleecy, woolpack clouds usually seen on a warm summer afternoon; the stratus are the horizontal veils or sheets that cover the sky more or less completely and which may develop into a general rain. The cumulus of the lower strata, one mile high above the ground, may grow upwards so as to form large domes, and in hot weather they become cumulo-nimbus when the heads are very lofty, some having been observed to reach six

or eight miles above the ground. See Chart 2. The alto-cumulus clouds are smaller, more huddled together like the backs of a flock of sheep, and they are from two to three miles high; the cirro-cumulus, from four to six miles high, appear to be still smaller, and they often arrange themselves in ranks or battalions and form the beautiful mackerel sky. All these clouds are formed by the rising of currents of air in a vertical direction, the flat bases showing the level where the temperature begins to be cool enough to cause the vapor to condense, while the sides and tops outline the relative amounts of pressure, temperature and vapor which are just sufficient for the saturation to begin. From a study of these elements we may compute the vertical gradients for each 100 meters, or for each 100 feet, of elevation above the surface of the ground, and these quantities are of great value to meteorologists. The stratus or veil clouds are formed in a very different way. Instead of producing the cooling necessary to condense the moisture by raising it to higher elevations, it may also be caused by the flowing of horizontal currents of air in contact with each other, as when a warm current passes over a cold one. When air from the south flows northward and air from the north moves southward into the same region, these currents generally overflow one another in two strata instead of mixing, since masses of air at different temperatures are quite reluctant to lose their individuality. This stratification of the air in horizontal sheets, flowing from the tropics and from the polar zones, is always taking place in the atmosphere, and the stratus clouds are generally produced somewhere along these surfaces of contact. The cumulus clouds therefore indicate, as shown in Chart 1, that the air is rising vertically in certain layers, while drifting eastward, and the stratus that it is moving horizontally with a different velocity in adjacent strata. The lowest stratus clouds are elevated fog; the strato-cumulus is about two miles high; the alto-stratus averages four miles and the cirro-stratus six miles above the earth.

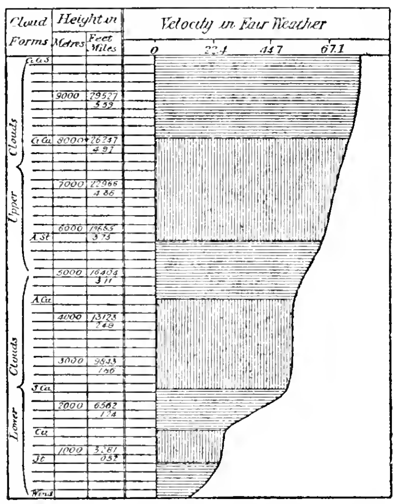

CHART 1. Example of the eastward movement of the upper air above Washington, D. C., in miles per hour. The average eastward velocity at the surface is 6 miles per hour; at 6 miles high it is 70 miles per hour in clear weather.

There is furthermore a stratification of the vapor contents of the atmosphere within every high cumulus cloud, which is interesting.

Take a lofty cumulo-nimbus cloud such as rises in the summer afternoon before a thunderstorm, from whose base rain may perhaps be falling, while the top is even higher than Mount Blanc piled upon the summit of the Himalayas. See Chart 2. There are sections which should be passed through the cloud, so as to divide it into three parts, which in fact differ from one another physically though they look alike to the observer. The lowest plane separates the saturated from the unsaturated vapor and marks the flat base of the cloud; the second is at the top of the saturated part and at the beginning of the freezing stage; the third is at the top of the freezing and at the bottom of the frozen stage. The freezing stratum is thin and is the place where the

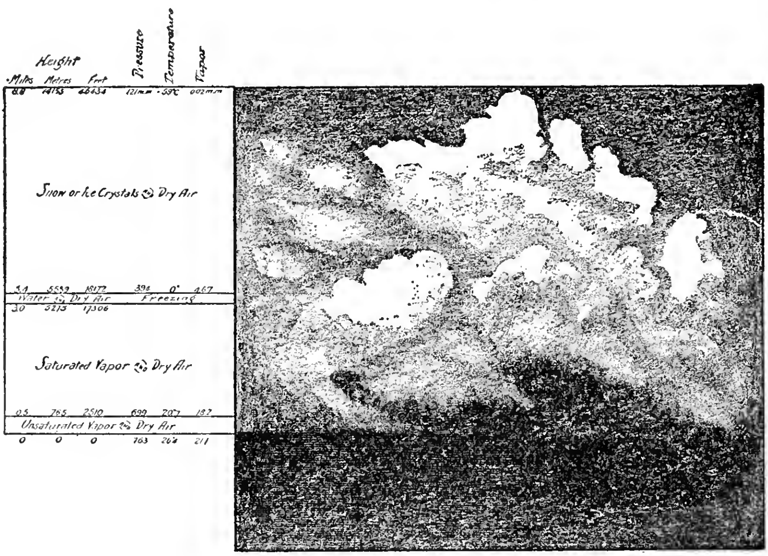

CHART 2. The distribution of pressure, temperature, and vapor tension in a lofty cumulo-nimbus cloud, observed by the Weather Bureau, July 29, 1896.

saturated vapor is passing into water at freezing temperature before it can crystallize into ice. A cloud has, therefore, these three portions, the lower consisting of vapor, the middle of water and the top of ice or snow. They appear to be alike because the light from the sun is reflected from drop to drop and from flake to flake in its passage through the cloud. The diagram gives the pressures, temperatures and vapor tensions at the ground, and at the several stages, while the height is indicated in miles, meters and feet. This illustration is taken from one of the loftiest clouds ever observed, and it was computed that the temperature fell from 26.4° Centigrade at the ground to —59° Centigrade or —74° Fahrenheit at the height of 8.8 miles. In summer time at the top of a high cloud the same temperature prevails that may be

found at the ground in the polar regions during the coldest days of winter. The obvious correction for the suffering of humanity due to the oppressive hot waves of summer is to bring down this upper air, or else arrange to visit it in floating houses.

The reader may have noticed that hail falls usually in the summer instead of in the winter, and have wondered what is the reason for it. The answer is simple. If we arrange a diagram so that freezing temperature is on the left and 100 degrees Fahrenheit on the right, and plot the limits of the rain, hail and snow regions in altitude, the result is shown in a set of curves which indicate the height at which it is possible for them to form respectively. In the summer when the

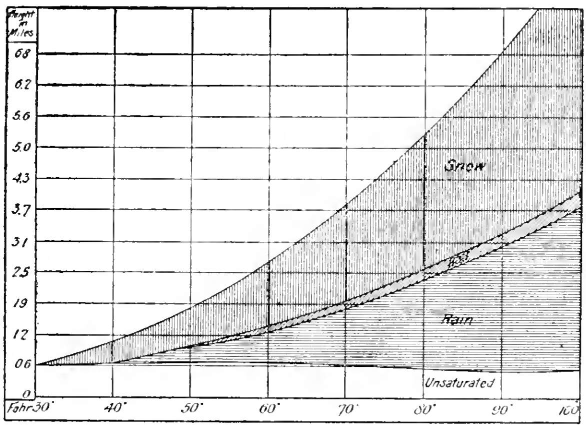

CHART 3. Distribution of rain, hail and snow in the atmosphere according to the temperature and height of formation. The curves mark the average boundaries of the several stages of the moisture in the atmosphere.

weather is warm there is more moisture in the air, it rises higher, till in extreme cases it may reach about seven or eight miles. The stages each become wider, though the hail is always confined to a narrow wedge-shaped region whose highest place is about four miles. Now in thunder-storms when there is powerful congestion and stratification of air currents in a vertical direction, the conditions are favorable for the forming of snow balls first by congealing the flakes in the lower parts of the upper stage; these fall slowly through the freezing stage and are coated with a layer of ice; they drop through the rain stage and collect a thicker covering of ice till they arrive at the ground as hail-stones. Such strata may be intermixed and arranged in alternate layers so that a nucleus of snow may fall through more than one pair of snow and freezing regions in succession, and thus cover itself with several layers of snow and ice, like an onion. Such stratified hail-stones are often found when they are cut open. This theory seems to

account for all the facts that have been noted in a simple and natural manner.

The most important use of the cloud observations is not the study of their constitution, but of their motions relatively to the surface of the earth. A cloud is a meteorological meteor, and moves in the stratum of air at approximately the same velocity as the atmosphere itself, so that a measurement of its direction and velocity gives that of the air current, just as a chip floating on a stream shows how fast the water is running. Repeated measures of this kind, when classified, teach us that the atmosphere flows with certain typical movements, and that by them the laws controlling its average circulation can be deter-

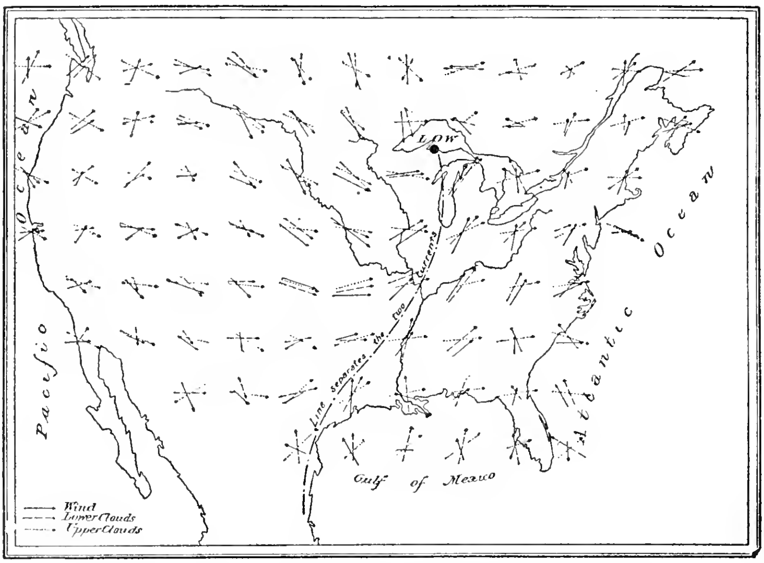

CHART 4. Storm in the Lake Region, a winter cyclone or low area.

mined. Now it is a fact that because meteorologists could observe the motions of the wind readily at the surface of the earth, but not in the upper strata of the air, they have relied too much upon conjecture in constructing the theories of the constitution of storms. The mathematical analysis has had therefore only an imperfect basis upon which to rest, and consequently it has made slow progress towards a complete solution of the problem. The international observations on clouds, during the year May, 1896–July, 1897, had for their immediate object the accurate determination of the motions of the upper air, with a view of testing the existing theories, and constructing new ones wherever necessary. This period of scientific observation is similar to the Tycho Brahe and Kepler stage of astronomy, when observations of the motions of the planets were accumulated for the use of the coming

Newton. To lay out the paths of motion in the atmosphere is just as important a work as that of finding the orbits of planets. There is more difficulty in doing it accurately because the motions of the air are much less steady and symmetrical than those of single masses like planets, comets and meteors, but it can be accomplished by patience and well-directed work. Unfortunately for lack of this sort of data much of our common meteorology is incorrect, and must be laid aside as of only an historical value. The subject is itself very complex, and it is unsuitable for a popular exposition, but an idea can be given of its scope and tendency by reference to the accompanying charts.

The Chart 4, marked 'Storm in the Lake Region' 'Winter Cyclone or Low Area,' is a composite map of the motions of the air around a winter storm central near Lake Superior. The upper or cirrus cloud movements are shown by the dotted arrows, the lower or cumulus, by those drawn with a broken line, and the surface wind by those with one unbroken line. The region affected by this storm extends from the Gulf of Mexico to the Lakes, and from the Atlantic Ocean to the Rocky Mountains. It is noted that the arrows drawn with an unbroken line and those drawn with a broken line generally blow nearly side by side, but that they differ from the dotted arrows in many cases, especially near the center of the storm and eastward to the ocean. This shows that the real storm circulation is confined to the lower strata as if it were quite independent of them. There is seen to be a slight deflection of the dotted arrows southward around the low; a corresponding chart of a high area would show a similar deflection to the northward of the center. This feature is brought out in Chart 5. Direction and velocity of the motions of the air in the cirrus, cumulus and on the surface. The arrows are not very smoothly laid down with reference to one another, but this is due to the fact that there were not enough observations taken in order to smooth out the local irregularities. Still, it is easy to trace a sort of wave motion, a crest over the high and a hollow under the low. As we come down from the cirrus, six miles high, towards the ground the sinuous motion becomes more pronounced, till in the strato-cumulus level the rotary component is dis-

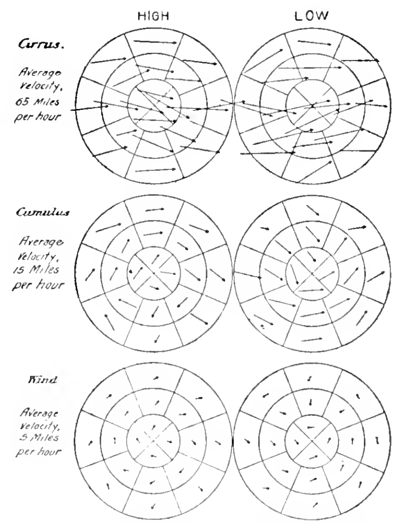

CHART 5. Direction and velocity of the motions of the air in the cirrus (6 miles high), the cumulus (1 mile high) and on the surface (wind).

tinctly seen, and in the cumulus it predominates. The length of the arrows shows the relative velocity, which is seventy miles per hour in the cirrus, on the average, forty-five miles in the alto- and strato-cumulus, fifteen in the cumulus and six on the ground. Compare Chart 1. The total motion of the upper air is made up of two parts, a rapid and quite steady eastward drift, and a local or secondary circular movement; these two combine and make up the observed circulation that actually exists. They are due to different causes, the first to the fact that the tropics are warmer than the polar regions, and that the earth is rotating on its axis; and the second to the fact that these two different temperatures seek to combine into an equilibrium by means of an interchange of heat through the air currents, especially in the strata from one to three miles above the ground. These counter currents flow against each other, and at or along their junction they produce rotations and whirl up cyclones or local storms. This is the law in the temperate latitudes from 30° to 50°; another law prevails in the tropics and possibly in the polar zones, though these belts have not yet been suitably studied. These counter currents can be readily seen on Chart 4 in the arrows drawn with a broken line, where a great stream flows from the northwest and recurves along the Mississippi Valley, while a second stream arising in the Gulf of Mexico flows northward, and recurves to the westward over the Lake Region. Along the edges of these currents is the place for rainfall, for the formation of cold waves, the production of tornadoes and thunderstorms. One can readily judge from relative lengths of the arrows on Chart 5 to what a disadvantage the forecaster is put in attempting to anticipate the probable storm action by using only the small arrows on the surface. He ought to have access to those of the higher strata as well, and this is the reason for the special efforts which have been made by the Weather Bureau through the cloud observations and the kite ascensions to in some measure overcome this defect. It is hoped that by means of nephoscopes and the necessary study of the facts already obtained to be able to make at least three simultaneous daily weather maps, one on the sea level, one on the 3,500-foot plane, and one on the 10,000-foot plane. This will give us three sections through each storm instead of one as at present. The forthcoming report of the Weather Bureau on the Barometry of the United States and Canada contains a discussion of these data and the necessary reduction tables for all the stations of the service. The sea level reduction tables were put in operation on January 1, 1902, and the tables for the other planes are nearly ready for use. There is reason for expecting that a good measure of success will attend these efforts to obtain practical results of considerable advantage in the art of forecasting.

CONTRIBUTIONS TO BIOLOGY FROM INVESTIGATIONS ON THE BREEDING SALMON.

By YANDELL HENDERSON, Ph.D.,

YALE UNIVERSITY.

IN science as in history, it often happens that facts bare and dry in themselves are infused with a sympathetic human interest, when viewed as events in the lives of men. Such an interest, focused in a single devoted investigator, and intensified by the pathos of his death, attaches to the name of Friedrich Miescher, late professor of physiology in Basel. In 1895 by more than twenty years of laborious investigation, he had brought to a successful conclusion one of the most brilliant and important researches ever attempted in biological chemistry. Up to that time few and incomplete reports of these results had appeared in print, the personal modesty and scientific caution of the investigator tempting him to delay publication. So it happened that the great mass of his researches was recorded in notes which only their author could decipher, when Miescher was seized by a mortal disease, and after a lingering illness, with the chapters describing his work completed in his brain, but with no strength to transfer them to paper, he died in the bitterness of a life work completed, but unpublished.

It may indeed be doubted whether the value of Miescher's work would have received full recognition twenty years ago, since many of his investigations then completed bear on problems which had formed themselves in the minds of few biologists of that time. To-day, however, these problems are of universal interest. The recent publication of two volumes* containing the few papers which Miescher had published, both on the salmon and on other subjects (which by themselves would entitle him to a high place among physiologists), together with extracts from his letters to his colleagues describing his work, and such of his notes as could be utilized, dates Miescher's work from the present time rather than the period of its performance.

For a proper understanding of the extraordinary tissue changes which he discovered in the breeding salmon, Miescher found it necessary to investigate fully the life and habits of these fish during their sojourn in fresh water. Of this subject little more was known than such practical knowledge as fishermen had developed. The position of Basel close to the head waters of the Rhine, the breeding ground of the

* Friedrich Miescher, 'Histochemische und Physiologische Arbeiten'; Leipzig, F. C. W. Vogel, 1897.

salmon, gave Miescher peculiar opportunities for this investigation. The salmon spawn during the latter half of November and the early part of December, or just before the shallows of the lakes and streams, where the eggs are deposited, are frozen over. These eggs are hatched by the warmth of the next spring. During the following year the young salmon live in the lakes and streams, and when a year old and from seven to nine centimeters in length swim down the river and out to sea. These facts were easily established. To determine the probable period of the salmons' return to fresh water was more difficult. By measurements of more than two thousand of the fish caught at Basel, together with statistics of those taken in the lower reaches of the Rhine and in other rivers of Germany and Sweden, Miescher found that the greater number both of males and females could be classed under one or other of three sizes. Contrary to what might have been expected the most numerous of these classes is that of the largest and oldest fish, while the least numerous is that of the small 'St. Jacobs' salmon. Unless it be supposed that some of the younger fish go to other rivers, which is unlikely, it is evident that not all the salmon of the proper age participate in every migration to fresh water. These considerations and others, based on the probable rate of growth of the fish, led to the conclusion that from two to three years after entering the ocean, many of the males and a few of the females make their first journey up the river to spawn. This accomplished, the fish return to salt water for another period of about three years. Then occurs a second migration to fresh water by a large proportion of both sexes. The males of this migration average seventy centimeters in length, the females seventy-six centimeters. Probably all of the salmon that have survived the dangers of marine life unite in the third migration. The average males of this age have attained a length of eighty-two centimeters, the females ninety centimeters. These differences in size Miescher regarded as the result of another period of life and growth in the ocean, between the second and third migrations, of at least two years. As only a few salmon of ninety-eight to a hundred centimeters length are taken, and these are all males, it is probable that the females as a rule make only two journeys to the spawning grounds during their lives, while the males ascend the river three or even four times. Within considerable limits of error the probable age of the largest salmon taken in the Rhine is therefore fourteen years.

By a careful comparison of the statistics of the number of the salmon taken in Holland and at Basel, Miescher found that any marked increase in the catch in the lower reaches of the river was regularly followed, after an interval of eight or nine weeks, by the appearance of an unusually large number of the fish in Switzerland. Basel is five hundred miles from the mouth of the Rhine, and if the average current

were only twenty-five miles a day, the fish must make their way through two thousand miles of water. In fact, however, the Rhine is throughout much of its course a swift flowing river, leaving Switzerland at a speed of four or five miles an hour; and the spawning grounds of the salmon lie above the falls and rapids south of Basel. Indeed even these considerations can scarcely be taken as a measure of the physical exertions of the salmon, since the swifter the current the greater becomes their activity. The heaviest runs of the salmon occur during June and July, although many fish whose condition shows them fresh from the sea are taken at Basel even during January. All these fish remain near the head of the river through the spawning season, and in the following December unite in a headlong rush back to salt water. The average duration of their stay in the Rhine is therefore from six to nine months, while in some cases as many as fifteen months must elapse from the day the salmon enter the mouth of the river until their return to the sea.

In view of these facts it would seem almost beyond belief, had not Miescher established it by absolutely complete demonstration, that the salmon never feed in fresh water. From the day they leave salt water until they return to it they maintain an absolutely unbroken fast. Careful examination of more than three hundred fish caught at Basel at all periods of the year, and of many taken in the lower reaches of the river just after the fish had left the sea, showed that not only was the alimentary canal empty of all food material, but the digestive apparatus was in no condition to handle nutriment even if offered it. The gastric mucosa was in a more or less desquamated condition, and alkaline in reaction. The gall bladder was empty, and the pancreas shrunken. Only two exceptions were noted, and these more apparent than real. In the stomach of one fish was found a large winged insect—quite undigested; in another a minnow—only partially digested. Of the latter case, however, Miescher records that the fish was caught near Basel in January, long after the spawning season, and was so extremely emaciated as to suggest that it must have been prevented in some way from escaping back to the sea.

The development of the genitalia (or sexual glands), occurring almost wholly after the salmon have entered fresh water, becomes of the greatest interest in the light of these observations; for the material built up in these organs must be drawn from the other tissues of the animal itself. To the problems involved in these tissue changes, as well as to those resulting from the expenditure of energy by the fish in their long journey up stream, Miescher devoted himself especially. His examinations and analyses of the salmon caught in the lower reaches of the Rhine at all periods of the year, and of those taken at Basel from January to May, show that the fish on their way up stream

are always in a well nourished condition. The intestines are surrounded by masses of fat; the muscles in all parts of the body are full and firm, and exhibit innumerable globules of oil within and between the fibers. The sexes are practically indistinguishable. The genitalia amount to only three-tenths of one per cent. of the weight of the animals. During the months from May to December a gradual but steady change takes place. The jaws of the males develop a beak three to five centimeters in length. The skin of both sexes changes color, losing much of its luster, and becomes loose. The fat about the intestines disappears first; then that contained in the muscles. Certain muscles of the back, which are less important in swimming, diminish to nearly half their original size; and their content of solids to an even greater extent. The muscles most important in swimming, however, are maintained in full vigor; and even in those drawn upon, it is significant that no loss of structure occurs; for on the salmon's return to the sea, this material can be replaced without a reconstruction of the tissue. Just before spawning, the average weight of both sexes is ten per cent. less than that of fish of equal length (eliminating the difference due to the growth of the jaws of the male) caught in May. In contrast with these changes is the growth of the genitalia. The testes or spermaries of the 'ripe' males amount to as much as six per cent. of their body weight, and the ovaries or roe of the females to twenty or even twenty-five per cent., and contain thirty per cent. or more of the total solids of the fish.

While the available information on the subject is as yet by no means so complete as is desirable, on the whole it indicates that the habits of the salmon in other parts of the world, and of other species, are at least similar to those of the Rhine. It is the belief of many of the guides in Maine and New Brunswick that the salmon in their streams do not feed after leaving salt water, and that the 'fly' used to catch them must appeal to their curiosity rather than to their appetite.* The salmon in the rivers of Scotland certainly resemble

* During the past summer Dr. C. W. Green, of the University of Missouri, has been carrying out investigations in conjunction with the U. S. Fish Commission on the salmon of the rivers of the Pacific coast. As these researches have not yet been published the writer is personally indebted to Dr. Green for this statement: "Concerning the question whether or not the 'King' salmon takes food in its run up the Sacramento, I have reached the tentative conclusion that it does not, in fact can not. Every salmon examined by me at the U. S. Fish Hatchery at Baird, Cal., and I examined many, not only had no food in the stomach and intestine but these organs were so much atrophied that only the smallest object could have been swallowed. Salmon a meter in length have an intestine not larger than a small lead pencil, and the stomach is reduced to less than seven centimeters in length. On the other hand in the stomach of one salmon taken direct from salt water at Monterey I counted eighteen squid and several small fish."

closely those of the Rhine according to a recent and very thorough investigation* by the Fishery Board of that country. The salmon in the rivers of Alaska, however, according to the report upon the subject by the United States Fish Commission,† exhibit certain differences which are significant of the physiological purpose of the habits and tissue changes in the breeding salmon. The principal runs of these salmon from the sea to their spawning grounds occur after the ice has broken up, and through a great part of the brief Alaskan summer. The number of fish swimming up stream at such times is so enormous that at places the current is almost choked by the struggling mass. A man wading through the shallows can kick the salmon out upon the shore by scores. The distances which these salmon must ascend is much less than in the Rhine—often only a few miles. Yet the difficulties overcome in struggling over shoals, leaping up waterfalls, and in attempting to pass the barriers of heavy timber recently erected by the canneries, are enormous. During this journey the males develop formidable looking beaks, and the genitalia grow to a size even greater perhaps than do those of the Rhine salmon—although exact figures are not available. At the same time both sexes become emaciated to an extreme degree, all the muscles and organs of the body being drawn upon apparently to supply material to the genitalia. It is certain that the fish do not feed after leaving salt water; indeed it is doubtful whether the beaks of the males would allow it even if they wished. But all the Alaska salmon—of which there are several species—differ from those of the Rhine in one respect. No adult salmon has ever been seen swimming down stream, and those which are washed down by the current die after reaching salt water. The greater number after spawning remain near the spot where the eggs are deposited, driving off intruding salmon that would disturb their nests, and marauding trout that would devour their eggs, until overcome by starvation and the exhaustion entailed by their journey and tissue changes, they die. They afford a striking example certainly of the sacrifice of the individual to the good—or the only 'good' that Nature seems to recognize—the perpetuation of the species; and this example is none the less striking because it can scarcely be supposed that these fish have any consciousness of the object for which they thus struggle and die.

The reason for these habits and tissue changes is probably to be found in the advantages which they confer upon the salmon in the

* Report of the Scottish Fishery Board on the Investigations on the Life History of the Salmon in Fresh Water, from the Research Laboratory of the Royal College of Physicians of Edinburgh; Edited by D. Noël Paton, M.D., 1898.

† *Bulletin of the U. S. Fish Commission,* Volume XVIII., 1898.

struggle for existence. The risks to which the eggs are exposed are indeed enormous. Many fail of fertilization; many are devoured or otherwise destroyed. Nor do the dangers to which the salmon are subject end with their hatching. Even if the growing fish escape the voracity of the trout in their natal streams, a host of enemies await them in the ocean. If the number of salmon from year to year remains fairly constant, it is evident that the chances for any one egg surviving to become a mature fish, to replace one of its parents and in turn have offspring, would be represented by two, while the chances of destruction would equal nearly the total number of eggs produced by the female, which amount to many thousand. Yet compared to the dangers which a deep-sea fish like the cod must escape, the hatching and early life of the salmon in the lakes and streams probably offer great advantages. Were the salmon to remain in fresh water, however, where the food supply is limited, their numbers would be at least as limited as are the trout. The same explanation probably holds good for their fasting in fresh water. Were they to feed during the spawning season they would leave nothing for the newly hatched fish,—and indeed the spawn of the preceding year and their own eggs would form, as in the case of other fish, a large part of their diet.

In the salmon nature offers to science, on a scale far exceeding the resources of any laboratory, an experiment in the metabolism of hunger —a demonstration that the energy liberated within the animal body comes not directly from the combustion of the carbonaceous substances of the food, as the energy of a steam engine from its fuel, but from the breaking down of the tissues themselves. Furthermore the conditions are reduced to their simplest terms. In the warm-blooded animals the maintenance of a temperature many degrees above their surroundings, necessitates a continual drain on the potential energy stored in their tissues. In the cold-blooded salmon, on the other hand, lying quietly, for weeks or months together, between the stones on the bottom of the Rhine, the processes of oxidation sink to a minimum, involving little else than the movements of the gills and the beating of the heart. Thus the energy latent in the fats, carbohydrates and albuminous substances, which the fish brings from the sea, is utilized almost wholly in the contractions of the muscles; and within the limits of the dynamic efficiency of these tissues this force is expended in the mechanical work of swimming. For physiologists the especial importance of this experiment lies in its bearing on the recent revival, in modified form, of the theory of Liebig, that the heat of the body is maintained by a combustion of the fats, but that the albuminous substances or proteids are the source of muscular work. Unfortunately the data upon this subject collected by Miescher are only partially available. The conclusions, however, at which he arrived, are sup-

ported by the thorough investigation of Dr. Noël Paton and his co-workers of the Scottish Fishery Board on the salmon of their rivers. They have determined the amount of the various fuel materials which disappear from the bodies of the salmon during their journey up stream. For this purpose they have analyzed all the tissues and organs of numerous salmon taken from the estuaries in the spring and early summer, just as the fish were starting up the rivers. They also found the amount of fat and albuminous material remaining in the tissues of the fish taken from the head waters of the rivers, a month or so later. By calculating from the numerical results of these analyses the equivalent figures for a fish of 'standard length'—arbitrarily taken at one meter—a fairly accurate basis of comparison was obtained. On this basis the difference in the composition of the tissues of the fish of the estuaries, and those of the head waters, reveals the number of grams of fat and albuminous material which the journey up stream costs the fish. The results show that, varying with the length of their journey—which in no case approaches the distance up the Rhine—the swiftness of the current overcome, and the other exertions necessary, the salmon in passing from the estuaries to the head waters, expend three hundred to six hundred grams of fat, and only sixty to a hundred and twenty grams of albuminous material. In the animal body the combustion of the fats and sugars is complete. They leave the system in the form of carbonic acid and water, after liberating within the tissues precisely that amount of energy which they would yield as heat, if burned in a perfect lamp or the most accurately constructed calorimeter. For the albuminous substances the combustion is less complete; but the amount of energy which comes from each gram decomposed within the body is determinable with no less accuracy than for the fats. To find the energy which the salmon expend in the ascent of the Scottish rivers, it is only necessary, therefore, to multiply the amount of fuel material expended by the number of calories which one gram of fat or albuminous material yields in a calorimeter. Thus it is found that the same six hundred grams of fat and one hundred and twenty grams of proteid, which the journey up the longer rivers costs the salmon, would heat sixty-five liters of water from the freezing point to boiling, or, to express the same amount in terms of mechanical work—would, if theoretical conditions in this regard were attainable, lift fourteen kilos (the weight of the 'standard fish' of the Scottish investigations) to the height of a hundred and eighty kilometers. But it must be borne in mind that the dynamic efficiency of few engines devised by man exceeds fifteen per cent.; and the investigations of physiologists have shown that the contracting muscles develop an efficiency only five to ten per cent. greater. From such data as these, together with the rate of flow of rivers, their length, and the time

consumed by the salmon in accomplishing the distance, it would be easy to reach fairly exact conclusions in terms of distance traveled, weights transported and fuel expended by the salmon, and to compare these results with those accomplished by a steamship; or to calculate the resistance of the water overcome by the salmon, and from this compare the relative advantages of the 'lines' of a salmon and those of a racing yacht. There can be little doubt that in the first case the advantages would be heavily on the side of the salmon, and that the yacht would show little if any superiority. But leaving aside such theoretical considerations—for which, it is only just to say, Dr. Noël Paton and his coworkers are in no way responsible—the investigations on the Scottish salmon show that eighty to ninety per cent. of the energy liberated by them in the muscular work of swimming is derived from the fats. The hungering salmon, like a hungering man or dog, reduces to a minimum the waste of protoplasm—that peculiar jelly of albuminous substances which constitutes the chemical framework and essential mechanism of the living cells of the body. In the salmon ascending a river, as in a man ascending a mountain, the energy liberated in the work done is supplied by a vigorous oxidation, and this is evidenced by an increased absorption of oxygen and excretion of carbonic acid. The elimination of nitrogenous substances from the waste of the tissue proteids is, however, only slightly increased.

No less interesting are the processes by which the genitalia develop, since they afford an example of constructive activity almost without parallel among animals; processes so characteristic of plants, on the contrary, that they were long supposed to exhibit the generic differences in the vital mechanism in the plant and animal kingdoms. Modern research has, indeed, shown that these great apparent differences are matters of degree, not kind. Plants can not now be considered as devoted solely to absorbing carbonic acid, and by means of the heat and light of the sun synthesizing carbonaceous material. They can, and when need arises, they do draw on their store of fuel, exhale carbonic acid, and even liberate measurable quantities of heat. On the other hand, physiologists have come to admit that the cells of the animal body, although wholly dependent on the vegetable kingdom for their materials and energy, yet possess wide powers of transforming the food substances to their needs. Uncertainty has, however, attended the efforts of the investigator of metabolism in man and the higher animals. Generally when the subject of the experiment fasts, growth stops. If on the other hand the subject is fed, the origin of the substances shown to appear or increase in any tissue—for instance the fats—may be assigned with almost equal chances to any one of the constituents of the food, or to a transportation from other tissues of the body itself. In the salmon, on the contrary, the conditions are of extreme simplicity

and clearness. The constituents of the genitalia are essentially different chemical compounds from the substances of the muscles out of which they are manufactured; yet the fact that their formation takes place wholly during the period of the animals' fast, leaves no other source for them. In the synthesis of these complex organic substances, the phosphorus—to mention only one element—can be traced with certainty back to the simple phosphates stored in the muscles of the salmon of the estuaries.

The mechanism by which this material is transported and transformed was the subject of much careful investigation by Miescher. He noted a marked increase in the functional activity of the spleen—an organ as enigmatic in the salmon as in man. He observed also a decrease in the blood supply to those muscles at the expense of which the genitalia grow, and an equal increase to the genitalia themselves. The special significance of these conditions lies in the fact that a very small blood supply, continued through the summer and autumn, would transport many times the amount of material which actually becomes a part of the genitalia. As these organs are not motile, and are apparently the seat of no marked oxidation, their respiratory needs would appear small. Nature, however, follows closely the principle of 'least action'; and Miescher advanced the theory that, aside from its part in respiration, the oxygen brought to the tissues by the blood exercises a tonic influence upon their constructive processes. Thus in the liquefying muscle the lack of oxygen causes a stoppage and reversal of nutrition. The cell contents are absorbed into the blood. In the genitalia on the other hand the excess of oxygen in which the cells are bathed stimulates their nutritional processes, and results in vigorous growth. This view is, of course, a pure hypothesis. Yet it is interesting on account of its close similarity to theories advanced now, a generation later, by pathologists to explain the causes of abnormal growths in the tissues of man.

Important as are the results of the study of the salmon thus far mentioned, none rank in value with Miescher's investigations on the chemical nature of the sperm and ova. These researches were practically the first in which there was an attempt to lay bare the chemical processes involved in fertilization and the formation of the embryo. The clue which Miescher furnished has been followed by others, until to-day we seem to be approaching a determination of the structure of the proteid molecule—the first step necessary to solving the problem of the chemistry of living matter. Modern histology has shown that the fertilization of the ovum, from which the animal body develops, consists essentially in the entrance of the nucleus of the spermatozoon or male cell, and its fusion with the nucleus of the ovum. The nucleus of the spermatozoon must therefore be regarded as the carrier poten-

tially of those characters physical and mental which the individual inherits from its male parent; as the nucleus of the ovum must be for the female parent. In the series of divisions by which the fertilized ovum separates into the cells which form the tissues of the body, the material or chromatin of the fused nuclei is with the utmost exactness divided equally to each, so that every unit of the system receives its share of this chemical endowment. This much the study of structure has taught us. But to the chemist the ultimate explanation of these processes seems to lie in the nature of the chemical substances composing the chromatin. In the salmon the ova and sperm are easily obtainable, and afford the unfertilized eggs and spermatozoa almost free from admixture with other matter. Accordingly the methods which Miescher employed for the separation of the constituents of these cells were simple, yet yielded the material sought in quantity and purity. The nuclei from the sperm proved to be composed mainly of a peculiar compound or series of compounds of the nature of ethereal salts. The acid radical was nucleic acid—a substance previously discovered by Miescher in the white corpuscles of the blood of mammals; the other component was an organic base which he called protamin. To the question as it presented itself to Miescher's mind, whether protamin may be regarded as the essential element in fertilization, the answer must be in the negative. Miescher found that protamin is not present in the sperm of the frog or the testes of a bull; and subsequent investigators have shown that it is absent even in some fishes. Yet in these cases it is apparently replaced, and the same functions performed by another substance of basic character known as histon. Miescher was led by these facts to the view that there is no one substance which can be regarded as the essential element in fertilization; but that the chemical processes involved are probably a series of reactions.

To attempt even an outline of the investigations and discoveries to which Miescher's study of the chemistry of the cell has led, would necessitate reviewing one of the most fertile fields of biological chemistry, and would involve much that is important in pathology as well. It is sufficient here to point out that what has been accomplished is in great measure the ripening fruit of the seed planted by Miescher in the quiet of his laboratory a generation past. In the final solution of the profounder biological problems, these investigations on the salmon and the researches to which they have led will probably be found to have contributed in large measure toward that object, which Miescher in one of his letters—almost the last before his death—expressed in the words—"There remains then this great question to be fought out by the biologists of the future—Is it chemical composition or cell structure to which we must look as the ultimate basis of vital phenomena?"

WHAT IS PHILOSOPHY?

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DURING the first third of the past century the intelligence of the world honored philosophy as the Queen of Science. In Germany, the capital of higher learning, students crowded into the lecture-rooms of the philosophers and accepted their teachings as gospel truths. Everywhere the deepest interest was manifested in the solution of the great problems of life. A powerful longing seized mankind to unravel the world's profoundest mysteries, and this longing, too impetuous to linger over an examination of the facts, satisfied itself in the study and production of metaphysical systems. A suggestive example of the immense influence wielded by the royal science during this epoch is furnished by the experience of Friederich Vischer, who declares that the entire time and energy of his youth were devoted to the interpretation of the world-riddle. "Indeed, it seemed to me in those days," he adds, "that a man had not attained his majority, and ought not, therefore, to be allowed to marry until he had at least dispersed the darkness surrounding the problem of free will and determinism."*

It was the golden age of philosophy, an age, however, which bore within itself the seeds of its own decay. Fichte, Schelling and Hegel, the members of the learned dynasty, defined metaphysics or philosophy as the ideal reconstruction of the universe from certain indisputable principles, the discovery of these principles being, for the most part, dependent on the possession of a special mental genius. Like Spinoza before them, they deduced from premises which they regarded as absolute, conclusions which seemed to them to be necessary. Closing their eyes to the facts, these thinkers trusted in their ability to account for those facts, by showing what would be the unavoidable logical consequences of certain axiomatic first principles. Experience they considered as valueless in this connection; the most that it could do was to *verify* the deductions of philosophy.† Schelling denies to it even this worth; the ideal construction or hypothesis of the thinker needs no such verification; it is self-sufficient, a law unto itself.‡ If the facts do

* Quoted by Volkelt in *Vorträge zur Einführung in die Philosophie der Gegenwart.*

† See Fichte's *Works*, Vol. I., p. 446; Vol. II., p. 359.

‡ Schelling, Vol. V., p. 325.

not square with the results of speculation, so much the worse for the facts. Although Hegel does not wholly depreciate experimental knowledge, he too lays chief stress on the *à priori* method.* Knowledge is boundless in its possibilities; no limit can be set to man's faculty of truth. Basing themselves upon such conceptions as these, Fichte, Schelling and Hegel undertook the construction of an edifice, which though grand and daring in plan and execution, had no foundation on the earth. And when philosophy loses its footing on the ground, it must Antæus-like perish in mid-air.

While the German metaphysicians and their following were proving by all the rules of logic what the world really *ought* to be, the exact sciences were modestly finding out what it actually *was*. The whistle of the locomotive suddenly awakened the speculator from his dreams, and called his attention to the wonderful progress of natural science with its fruitful methods and useful results. A reaction soon set in against Hegelianism, and its star sank. Men grew aweary of fanciful speculations and longed to return from the clouds to the realities of the material world. Railroads were built. Trade and commerce took enormous strides forward, commercial and polytechnical schools were founded. All energies were directed toward the discovery, explanation and application of material laws, and the exact sciences took the place in the public confidence once held by philosophy. Liebig, the great chemist, introduced the laboratory into German universities. Alexander von Humboldt made a reputation for himself as a scientist. Important discoveries were made in France and Germany by physiologists like Müller, Weber, Flourens, Magendie, Leuret, Longet.† Philosophy lost her crown; despised and forsaken by a world that was now as extreme in its contempt as it had formerly been extravagant in its praise, there was none so poor to do her reverence. The philosopher was described as one speaking of things of which he knew nothing, in words which no one could understand. The mistake lay in identifying all philosophy with a temporary one-sided phase of it. The hue and cry was raised against the persecuted queen. The natural sciences, of course, renounced their allegiance and established an antiphilosophical republic of their own. They deluded themselves into believing in the possibility of excluding philosophical conceptions from their realm; they simply succeeded in introducing loose, illogical notions into their explanations, notions that careful thinkers had long ago rejected as unsatisfactory. Materialism, the simplest and most insufficient solution of the world-problem, became the order of the day.

Conditions like these could not fail to intimidate philosophy. Mis-

* Hegel, Vol. VI., pp. 53 and 78.

† See Lange, *History of Materialism*.

fortune is apt to humble us. It is not strange then that the succeeding generation of philosophers should have been meek, and that even so late as 1874, Wundt should have felt the need of proving that philosophy had a right to exist, and might justly claim a place among the sciences.*

This period of reaction, however, was as transitory as its cause had been. The disturbed pendulum was simply swinging to the other side before resuming its regular movements. The metaphysical need or impulse, as Schopenhauer terms it, is too powerful in man to be permanently suppressed. To ask *why* is one of the noblest functions of the human being; to stifle such inquiry would be equivalent to destroying all intellectual activity. It cannot be stifled. Philosophy is not of an age, but for all time. The last philosopher will die when the last man dies, unless, indeed, that individual happen to be a hopeless idiot. Whoever is capable of thought at all will attempt in some way, be it ever so crude, to explain to himself the world and his place in the world. 'What does it all mean?'† 'What is it all for?' are questions which force themselves upon every intelligent being, and are answered by him according to the light that is in him. (Indeed, his queries themselves are pregnant with entire metaphysical systems.) Nor can the exact sciences themselves operate without metaphysical conceptions. However violently they may protest against metaphysics as though it were the plague itself, they inevitably succumb to the disease, if disease it be. Is the theory of descent utterly free from the taint? Is the atomic theory which Greek philosophy originated in the fourth century B. C. any the less metaphysical because it is promulgated by modern scientists? Is not the attempt to reduce all material facts to their ultimates, matter and force or energy, metaphysical? Is not the theory of the indestructibility of matter and the conservation of energy, as conceived by many, metaphysical? Is not the attempt to refer all energies to one ultimate energy a bold and grand attempt to reach a unity, a first principle, on which all else depends? And what can be more metaphysical than that? In truth, the philosophical tendency to reduce plurality and diversity to unity, to find one common principle that may be able to explain *all* phenomena, prevails in every scientific procedure, because it constitutes the very essence of mental activity. We can not resist the impulse to unify our experiences, we would reach a comprehensive survey of *all* existence, discover the principle or principles which will explain *all* facts. The different sciences dealing with different sets of facts may find ultimates capable of accounting for their facts respectively, but only by ignoring other facts. They give us, as it were,

* Wundt, *Aufgabe der Philosophie.*

† 'Was ist der Sinn der Welt?'—Lotze.

cross-sections of reality while we wish to get a comprehensive view of the whole. Physics may be able to explain *its* facts by assuming the existence of homogeneous atoms and force, but can the chemist understand *his* phenomena without presupposing the *qualitative* difference of such atoms? Can the biologist undertake to interpret life with purely mechanical principles; can he reconcile the purposiveness of organisms with the mechanical theory of causation? Will the psychologist, who deals with states of mind or consciousness, be able to account for the existence of these from the physicist's principles, atoms and motion? A science is needed that will consciously and methodically aim to bring order into this chaos, that will consider *all* the facts, and, if possible, *unify* these facts. It will subject the principles offered by the various sciences to the most critical examination, compare them with one another, point out their inconsistencies where such exist, it will in short, rectify, harmonize and if possible *unify* results. Such a science is philosophy. Its need is apparent. If men are bound to philosophize at all, it is a reasonable demand that they should do the work well. We cannot leave the solution of the greatest problems to chance, to the haphazard methods of persons unskilled in such work, and prejudiced enough to adjust the facts to their theories. Here as everywhere else, he will do the best work who has the best training, and concentrates his entire time and energy upon the field of his choice.

Such reflections as these have brought the modern world back again to philosophy. The philistine is defined as the man without intellectual needs, and the philistine alone sees no need of philosophy. The *great* scientists do not allow their occupation with the details of reality to blunt their vision of the whole. They look up from their microscopes occasionally; they can not rest satisfied with blindly staring at the minutiæ; they aim to understand things by seeing them in their relations to the whole.

The measurement of the time required for a current to pass through the sciatic nerve of a frog will not, taken by itself, make us any the wiser. Mere facts must be made the stepping-stones to something higher. Our age is becoming more fully aware of the need of philosophical study. This is evident from the renewal of the philosophical activity in all departments of knowledge. Protestant theology is striving after a rational explanation of dogmas—heresy trials show that! Catholicism has its philosophy; it accepts the conceptions of Thomas Aquinas, whose source is Aristotle. In jurisprudence, economics, politics, sociology and history the philosophical tendency is manifesting itself. Mathematicians, too, are speculating concerning the nature of number, space and related notions. In the words of Wundt the view is spreading among natural scientists 'that the mere description and combination of the facts of a limited field will no longer suffice, but that it is

the highest aim of the particular branches of natural science to co-operate in obtaining a *comprehensive* conception of nature.'*

A further evidence of the intensification of philosophical activity is offered by the increased sale of philosophical books, the publication of philosophical journals, and the strengthening and establishment of departments of philosophy in our universities. Our own country, though frequently accused of being the most materialistic nation on the globe, is becoming a zealous admirer of philosophy. Our philosophical journals are increasing in number and in circulation, and improving in scientific merit, while our great publishing houses are issuing the works of noted authors of all countries, and rendering them accessible to a wider sphere of students.

We have been discussing in the foregoing the fortunes and nature of philosophy proper, during the immediate past. We identified the term philosophy with *metaphysics*, or the science of first principles. But philosophical study does not occupy itself wholly with metaphysics. That in truth is its very highest and hence latest function. It cannot attempt to offer an explanation of the facts of the world, until it has become acquainted with a large body of these facts. Now the world as a whole presents us with two sets of phenomena, physical and mental, and corresponding to this division we have two classes of sciences, physical or natural science and mental science. The former deal with the manifestations of the external or physical universe, with lifeless and living matter; the latter, with the manifestations of the inner world, with consciousness or mind. The fundamental mental science is called psychology, which analyzes, classifies and explains states of consciousness. On it are based such studies as logic, æsthetics, ethics and the philosophy of religion. Psychology asks such questions as these: What are the nature and conditions of sensation, perception, imagination, memory, conception, emotion, instinct, impulse, attention, volition; all of these states being facts of mind or consciousness. Logic asks: How does the mind act when it reasons, when it reaches sentences that we regard as true? What are the forms or laws or principles of reasoning? What are the methods employed by the scientist in his investigations? What, in short, are the rules of deduction and induction? Æsthetics asks: What in the soul and in objects is it that makes us call things beautiful or ugly, sublime or ridiculous? What makes a production a work of art; what are the laws or principles governing the artistic? Ethics asks: What are the characteristics of morality? Why do we designate one act as right, another as wrong? What forms the criterion or standard with which moral facts are measured? We feel that certain courses of conduct are wrong. What is the nature and origin of this feeling? How is it developed? What,

* Wundt, *Essays*, p. 4.

in short, are the laws or principles governing the moral world, and how do these principles find expression in the life of man? Closely related to psychology and ethics, and furnishing them with a large body of facts, are the social sciences, which consider the thoughts, feelings and volitions of social organisms, or man in society; the ends which such organisms serve, and the means with which such ends are reached. Society, unconsciously or consciously, aims to realize certain ends. What are these ends? How are they realized? We must study the forms which realize them, we must study human customs and institutions, and trace their development. Sociology is the name given to the science which performs this task. These ends cannot be realized without organization, or the state. What are the forms of government, and how do governments realize their ends? The theory of the state, or the science of politics, discusses these questions; it bears the same relation to sociology that ethics bears to psychology. The philosophy of religion investigates those inner facts of human experience which we call religious facts, and is, in so far as it does this, a branch of psychology. But it also studies their external expression, the different forms, and traces the development of positive religions in order to discover from the material thus presented the principles common to all religions. What is the idea which seems to be realizing itself in the history of religion?

The philosopher must pay attention to the fundamental mental sciences, psychology, logic, ethics, æsthetics and the philosophy of religion. These sciences differ from the so-called natural sciences only in their content or subject-matter, not in their general form or methods. All sciences, both physical and mental, occupy themselves with observing phenomena and reducing them to laws, employing all available means of accomplishing this task. But no science restricts itself to a mere registration of laws; it seeks to discover the relations between these laws, to connect them, and to reduce them to their simplest forms. The physicist refers all material manifestations to one underlying principle or force. The biologist finds it impossible to explain *his* facts by means of purely mechanical principles. "How can we reconcile the purposiveness of organisms with the principle of causation?"* The psychologist, again, is brought into contact with another group of facts which the atomic theory cannot account for; mind cannot be explained on a purely materialistic basis. The scientist may be able, by means of mechanical laws, to show how a planetary system was evolved from chaos, but can he account for the existence of the amœba? Can his principles account for the simplest fact of consciousness? To quote Kant's celebrated words: "It seems to me," he declares in his *Theory of the Heavens*, "that, in a certain sense, a man may say without pre-

* Wundt, *Essays*, p. 5.

sumption: *Give me matter and I will build you a world. . . .* But can he make the same boast with reference to the simplest plant or insect? Can he say: *Give me matter and I will explain to you the evolution of a caterpillar?*"

Each science endeavors to reduce the most diverse facts with which it deals to identity, to one underlying principle. Heat, light, sound, electricity are different forms of some underlying force or energy. Are states of consciousness referable to the same force, or must we assume another ultimate, of which both physical and mental facts are the expression, as the monists hold?

All these are problems that are worth considering. The difficulty of solving them and the disagreement existing between the attempts to solve them suggest another problem. The human mind has a tendency to unify, to reduce facts to ultimates, to first principles. What is the value of this tendency as a means of reaching truth? Can we know anything about these things? The instrument of knowledge, the human mind, without which there could be no science at all, is itself a fact which needs to be explained. We evidently employ the same methods in the different branches of knowledge, we explain facts by referring them to their antecedents, simply because this is the function of the mind. But is there no limit to this search for antecedents or causes? What epistemological value has the causal instinct? In fact, what does human knowledge consist in, and how is it possible, as Kant asks? Define its limits, before you set out on the vast sea of speculation. We need a science which will examine the nature and validity of knowledge, a *theory of knowledge*. As Helmholtz declares, no age can with impunity refuse the task of examining the sources of our knowledge and the ground of its validity. The different sciences employ the categories of thinking without investigating their validity. Philosophy must regard with suspicion everything that is not clear as day; it is 'nothing, if not critical.' In his attempt to explain the sensible world, the scientist often has recourse to the suprasensuous. Can we know anything of the suprasensuous or must we confine our efforts to the study of what our senses present to us? Must we accept DuBois-Reymond's verdict? "Concerning the riddles as to what matter and force are, and whether they can think, the natural scientist must once for all decide upon the verdict: *Ignorabimus*."* Or shall we protest with Haeckel against the position that there can be invincible barriers to *Naturerkennen*. There are many other problems which suggest themselves to an epistemology, or theory of knowledge.

Such a science not only forms the prelude to the most important part of philosophy, to metaphysics, but also assists the thinker in discover-

* DuBois-Reymond, *Grenzen des Naturerkennens.* Galileo made a similar statement.

ing the inconsistent and premature metaphysical conceptions which stealthily creep into all branches of knowledge. The natural scientist frequently rails against metaphysics in the very words of metaphysics, without knowing that his entire mental activity is based on metaphysical preconditions. Metaphysics is the old man of the sea whom the scientific Sindbad carries on his own shoulders, without, however, feeling the load.

After having studied the limits and validity of human knowledge, the philosopher is ready for the construction of his metaphysical system. He calls to his aid the history of philosophy, which unrolls before him the thoughts of past ages and bids him profit by their experience. The history of philosophy must not be regarded as 'a disconnected succession of arbitrary individual opinions and clever guesses,' it is not a formless aggregate of errors, not a series of unsuccessful attempts to reach truth. It is not a Sisyphean labor, a Penelopean woof. The history of philosophy is a development, an evolution, in which the forms which follow generally show an advance over what precedes. And even if it were a mere catalogue of errors, it would be of service to the metaphysician by pointing out to him the lines of thought that have ended in blind alleys; it would warn him against wasting his energies in fields that have been worked over. The man who knows how a solution can *not* be effected is on the road to knowledge.

A STUDY OF CALMS.

By Professor EDWIN GRANT DEXTER,

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AMONG the suggestive things which have been noted in the course of a series of studies which I have made in an attempt to discover the influence of the weather upon human conduct, no one has been more interesting or unexpected than the seeming effects of calms. Few people are immune to weather influences, and most of us are in a more or less apologetic mood for our behavior during some meteorological condition. East winds and leaden skies are made scape-goats for many a sin of omission or of commission, but it has not been my observation that conditions of calms were often used in that way.

That they do exert a marked influence upon human activities I hope to demonstrate in this paper. The method is wholly an empirical one. Various records of the occurrence of different abnormalities of human conduct were made use of, and the average daily occurrence of these phenomena for a number of years, compared with their average daily occurrence under definite meteorological conditions. The study was for the city of New York—a fact that must be borne in mind since it has an important bearing on the present problem—and covered a period of twelve years, for every day of which the mean temperature, barometric pressure and humidity, the wind movement, the precipitation and the character of the day were determined and used in the tabulation.

The conditions covered by this problem, the number of data, and their sources are as follows:*

Registration in Public Schools.........	118,020	School records.
Deportment in Public Schools..........	14,020	School records.
Deportment in Penitentiary...........	3,981	Penitentiary records.
Arrests for assaults and battery (males)	36,627	Police records.
Arrests for assaults and battery (females)	3,981	Police records.
Arrests for drunkenness (males)......	44,495	Police records.
Arrests for insanity (males)..........	2,467	Police records.

* Fuller studies have been published as follows: 'Conduct and the Weather,' Monograph Supplement, No. 10, *The Psychological Review; The Pedagogical Seminary*, April, 1898; *The Scientific American Supplement*, June 3, 1899; *Science*, August 11, 1899; *Appleton's Popular Science Monthly*, September, 1899; *Educational Review*, February, 1900; *Nature*, February 11, 1900, *Annals of American Academy of Political and Social Science*, October, 1900; Popular Science Monthly, April, 1901; *International Journal of Ethics*, July, 1901.

Arrests for insanity (females)	1,097	Police records.
Suicide	2,946	Police and coroner's records.
Deaths	74,793	Board of health records.
Policemen off duty for sickness	191,137	Police records.
Clerical errors	3,698	Bank records.

The whole number of data considered is 497,262.

The only influences which I wish to discuss in this paper are those of calms. For present purposes I have considered those days as calm, for which the total registration of the anemometer for the twenty-four hours was less than 100 miles. This would mean an average hourly movement of about 4 miles.

To explain more fully the data given above and discuss them: Under 'Registration in the Public Schools' is shown the exact number of single day's attendance which the registers of the schools studied would have shown if none of the pupils had been absent. As a matter of fact 9.2% were regularly absent. These absences were of course distributed throughout the whole school year, and, consequently, throughout all kinds of weather. As would naturally be expected, they varied to a marked degree with the weather. On excessively hot and cold days, on very windy or rainy days, there was a falling off in attendance for reasons that are patent.

The fact of importance from the standpoint of our present study is the falling off on calm days. For the two years studied, the average of absences for days upon which the total movements of the wind was less than 100 miles, was 29%: more than three times the average for all kinds of weather,—an excess of 214% based upon the expected, or average number. Here is something which on *à priori* grounds would scarcely have been looked for. Why were the pupils at home? The most logical answer to that question is, I believe, that they were not well enough to go. That they were suffering from some of the many indispositions to which childhood is subject. Not necessarily measles, nor mumps, nor scarlet fever, but the simple lack of condition which the woman in the next flat understands perfectly when his mother remarks that 'Johnnie was not feeling well this morning, so I kept him home from school.' To be sure, other matters keep the children home on calm days, such as company, funerals and parades, but these things occur just as frequently in other kinds of weather and we can not reasonably suppose that the conditions which we have found are due to them.

The next class of data has to do also with deportment, though not in public schools. It is marked 'Deportment in the Penitentiary,' and is based on the record of the prisoners committed to solitary confinement in the dark cells at the penitentiary on Randall's Island. The number so punished for misdemeanors occurring on calm days was 80% of the daily average for all kinds of weather, showing a deficiency of 20%.

The data for the next five classes of misdemeanors mentioned above were all taken from the blotters in the record room of the New York chief of police. Crime is there classified under 136 different heads, and the arrests for each, recorded for each day. The classes considered by me were studied for periods varying from two to seven years. The figures indicate the total number of arrests made for those periods, by the entire police force of old New York, the present borough of Manhattan.

The terms 'assault and battery' and 'drunkenness' are, I think, self-explanatory. Each arrest for 'insanity' meant that some one had been picked up on the streets in a state of acute mania, or that the police had been called to some house to remove a person in such a condition. In most cases it probably meant an initial attack of the disease, or the beginning of a recurrent attack. Otherwise the person would have been in an asylum, or other authorities than the police would have been appealed to.

To state in the briefest possible manner the seeming influence of calm days upon the distribution of these crimes: The number of males arrested for assault and battery upon such days was 89% of the normal,—by which term I mean the average daily occurrence for the whole period studied; of females for the same crime, 45% of the normal; of males for drunkenness, 77%; of males for insanity, 67%; of females for insanity, 34%. The figures show that there was a deficiency in the occurrence of all these crimes, the magnitude of which may be computed in each case by subtracting the percentage of occurrence from 100%, which is expectancy. In securing the data for suicide, two sources were made use of. In fact it is not solely a study of successful suicide, but of suicidal intent. From the standpoint of our study it is just as valuable a datum from which to work, to know that somebody tried to die at his own hand even though he did not succeed, as to know he was successful in the attempt. An attempt at suicide is a crime and is so recorded in the police records, which were tabulated for a period of five years. This gave us 984 of our data. The remainder were secured by going over some 28,000 death certificates for the same period in the coroner's office. The results showed that but 63% of the normal number of suicides (and unsuccessful attempts) occurred on calm days.

The next class of data given in the list is that of death. It is based upon the record of deaths for all causes in the city for a period of two years. In it we have a notable difference from the crimes and misdemeanors we have been studying, in that the occurrence for calm days was above the normal, being 104%. In this respect it resembles the study of attendance in the public schools, and also the last two classes of data given, those of the 'policemen off duty for sickness' and of

'clerical errors.' Of these two, the data for the first were taken from the annual reports for five years of the chief of police of New York city. It was not there stated that sickness was the cause of absence from duty, but it is safe to assume that it was the usual one. It is, however, rather interesting to note that immediately following Christmas, New Years, and other holidays, an unusual number was laid off, but we may charitably suppose that the weather was excessively deadly in its effects at those times. The tabulation shows that 105%, or 5% in excess of the normal number, were off duty on calm days. This would hardly be more in accordance with our expectation than was the school attendance under such conditions. If perfectly calm days were the most agreeable of all kinds we might suppose that our stalwart guardians of the peace had chosen them for picnics, but gentle breezes are generally accepted as being more delectable than dead calms, and we must look for some other causes for the absence of bluecoats under the latter conditions.

The last class of data given, that having to do with 'clerical errors,' was studied as a make-shift. I wished to determine the influence of different weather conditions upon the intellectual as well as educational states of man, and to that end sought long and earnestly for school records which showed a daily marking of class work, but without success. If any teacher who may read this has such, I should be very grateful to him if they could be placed in my hands. While wondering what other records might be made to supply the lack, I came across the statement that in the Bank of England certain sets of books, an error in which would prove cumulative and produce disastrous results later on, were never worked upon during some kinds of weather, especially London fogs, as it had been proved that clerical errors were much more frequent at such times.

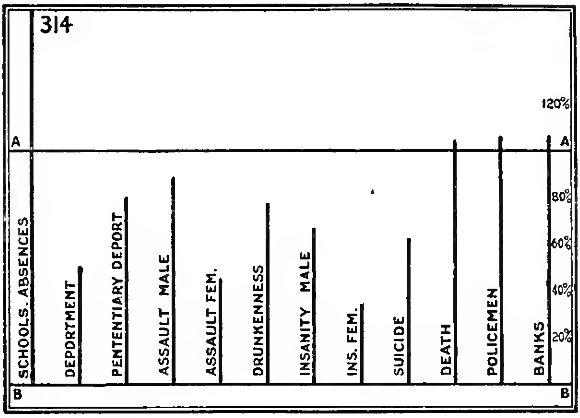
Following the clue here given I gained access to the books of some of the largest banks in the Wall Street district, with the result that in the records for two years, the number of errors stated were found and tabulated with reference to their daily occurrence. The results showed 104% of the normal, or an excess of 4% for the calm days.

To state in a sentence the occurrence of data of all these classes under the condition of calm: absence from school, death, policemen off duty, and clerical errors were all above the normal, while misdemeanors in school and penitentiary, arrests for assault and battery, drunkenness and insanity, and suicide, were below.

The facts so far given do not show whether the change with an increase in wind was a gradual one or not. As a matter of fact it was not. Had it been so, there would have been less excuse for this paper. The most striking thing about the curves upon which it is based is the sudden change which takes place in the occurrence of nearly all the

Table showing Prevalence during Calms of Phenomena studied.—One Hundred Per Cent. Equals the Normal or Expected Number.

Schools; absences	314%	Insanity (male)	67%
Schools; deportment	50%	Insanity (female)	34%
Penitentiary; deportment	80%	Suicide	62%
Assault and battery (male)	89%	Death	104%
Assault and battery (female)	45%	Policemen off duty	105%
Drunkenness (male)	78%	Banks, Errors in	105%



activities (or cessations of activity in the case of death) with a slight increase in atmospheric movement. In the case of arrests for assault and battery and for insanity (both males and females), and of misdeeds in the penitentiary, all of which had shown deficiencies for calms —and some of them very large ones—excesses were shown for wind movements between 100 and 150 miles per day, while misdemeanors in the schools were also above the normal before a movement of 200 miles had been reached. On the other hand, policemen off duty and death, both of which had been excessive in number during calms, took a sudden drop as the wind arose, and showed deficiencies for the next wind group (100–150 miles). Suicide, drunkenness and clerical errors alone showed gradual changes with the wind. The appearance of the curves as a whole is such as to lead me to place calms in a class by themselves as far as wind influences are concerned. High winds seem to have an influence peculiarly their own, gradually merging into that peculiar to moderate and slight movements, but when the aerial stagnation of 100 miles per day or less is reached a sudden change takes place, and certain human phenomena suddenly increase in numbers, while others drop almost to a vanishing point. Which are the ones in excess? Absence from school, absence from police duty, clerical errors and death. But absence from school means sickness, absence from duty the same, clerical errors the same in milder forms, and death the same at its maximum.

To restate: *during calms, those life phenomena which are due to depleted vitality are excessive.* But let us return to those phenomena which were deficient in occurrence during calms. They were misdemeanors in public schools and penitentiaries, cases of assault and battery, insanity, drunkenness and suicide. To analyze each briefly: In the public schools, sins of commission rather than sins of omission are usually the occasion of bad marks in deportment. It is usually the active, energetic boy, the one with vitality to spare who gets the demerits. The anemic youngster may never stand at the head of his class, but he is very likely to delight his fond mamma with a mark of 100 in deportment. If that be so, and I speak with authority upon this point if upon no other, disorder in the school room is an active thing, and an evidence of excessive vitality. With the penitentiary inmate I have had less experience, but upon *à priori* grounds would argue that what is true for the child in question of deportment would not be radically different for the adult. In fact the wardens in charge, upon being questioned on the matter, gave it as their opinion that the prevalence of disorder bore a pretty close relation to physical health, varying directly with it; that order was only preserved through evidence of superior force on their part; that a sick person was always a good one, but that with a return to health conditions were frequently very different. We may then conclude that in the penitentiary misdemeanors are evidences of excessive vitality.

With persons arrested for the crime of assault and battery the same is, I believe, demonstrably true. One might feel like fighting and perhaps more frequently does feel so when possessed of 'that tired feeling' which is the fortune of patent medicine venders, but to *feel* like fighting without doing so, never brought a man before the police judge for the crime which we are considering. There must be both the inclination and the consciousness of strength to back it up before one would be likely to figure in this class of data.

In the case of the next class, that of arrests for insanity, we shall take the word of the psychiatrist that acute mania increases with any condition which tends to augment the output of nervous energy. The daily fluctuations in strength which all have experienced are not so much those of physical, as of nervous energy, if the distinction may be made, and with any having tendencies to mania the results would be those which our records showed.

With the occurrence of drunkenness and of suicide we have seeming contradiction to the belief which I have been attempting to maintain for the other phenomena which were deficient during calms, namely that they were evidences of excessive vitality. To discuss the peculiar problem which each of these presents would take us too far from our present subject, so I will simply refer any who are interested

in following the subject further to papers already published by me on the subject.*

With these possible exceptions we can say: *that during calms those life phenomena which are due to excessive vitality are deficient in number.* If these theses have been sufficiently defended, and figures are not in existence with which to refute them, the next logical question would be, 'Why?'

Two hypotheses may, I believe, be presented in answer. The first is based upon the general facts bearing upon ventilation, and the second upon those of atmospheric electricity. The first would only be applicable to the conditions of large cities—and I will again call attention to the fact that all the data of the present problem were for New York City—while the second would be valid for any spot on the earth's surface. In discussing the first I would call attention to the fact that combustion of any sort, whether within the lungs of animal organisms or in the ordinary processes of burning, depletes the air of its oxygen and surcharges it with carbonic acid gas. If the normal proportions of oxygen are to be maintained in the immediate vicinity of such combustion, fresh air must by some means be brought in to take the place of that, the normal mixture of which has been disturbed. We are quite familiar with these facts in their bearing upon the ventilation of buildings, but there is no difference except that of magnitude between a building in which the air is being robbed of its oxygen through combustion, and a city in which the same process is going on.

Three million animal organisms (not all human) and half as many more fires, all without adequate vegetable organisms to reverse the process should, we would argue, make tremendous inroads upon the atmospheric stock of oxygen. That this is true has been demonstrated by Dr. J. B. Cohen in an article appearing in the *Smithsonian Reports* for 1895, p. 573. He there shows that the proportion of carbonic acid gas varies to a very marked degree in the center of the city of Manchester, England; that the variation extends from the normal amount at times, to more than four times that amount at others, the average being nearly three times the normal. Although he makes no reference to the fact, it is, I believe, safe to assume that these variations bear a fixed relation to wind movements. Certainly when the wind was very violent, no considerable difference could exist between the composition of the atmosphere in a great center of population and in the surrounding country where the normal mixture of gases would be found. It is safe also to assume that what was true for Manchester would be for New York City, and to assume at least as a working hypothesis that

* 'Drunkenness and the Weather,' *Annals of the American Society of Political and Social Science*, November, 1900; 'Suicide and the Weather,' POPULAR SCIENCE MONTHLY, April, 1901.

during calms the atmosphere for that city contains an excess of carbonic acid gas and a consequent deficiency of oxygen. The devitalizing effect of the former gas upon life processes and the importance of the latter to them are facts too well recognized to need discussion here. That they are demonstrated by the conditions stated earlier in this paper I shall maintain until some more tenable hypothesis is brought forward.

Some interesting facts not already alluded to are suggested by this study, and in conclusion I shall mention two of them very briefly.

First, there would seem to be reason to infer that the influence of calms upon children is more marked than that upon adults. The basis for this belief is found in the fact that the absentees from school were increased three-fold during their prevalence, while no one of the classes of adults was affected to anything like such an extent.

Second, that women seem to be more sensitive to such influence than men. Evidence of this are to be found in the study of arrests for assault and battery where the sexes were tabulated separately.

In explanation of my own conception of the whole problem of weather influences, I would say, in closing, that we cannot suppose peculiar meteorological conditions to be the immediate cause of many of the abnormalities of conduct which vary with them. I have determined that suicide is much more frequent when the barometer is low than when it is high, yet would not wish to assert that low barometrical conditions ever drove a man to self destruction. The only thing supposable is that during such atmospheric conditions, the general emotional states are of such qualities that other things are more likely to do so.

This would be just as true for any of the other abnormalities of conduct studied. We can on the strength of the whole series of studies claim to have demonstrated that the metabolic processes of life to some extent vary with the weather states, and that these variations in metabolism make themselves evident both through physiological and psychological manifestations. More than this we do not at present claim.

OUR FOREIGN COMMERCE IN 1901.*

BY FREDERIC EMORY,

CHIEF OF THE BUREAU OF FOREIGN COMMERCE.

THE commercial reports of diplomatic and consular officers for the calendar year 1901 record continued growth in the sales of many lines of manufactures from the United States in foreign markets and the increase of the general concern in Europe as to the possible results of our industrial competition. Although the figures of our exports compiled by the Treasury Department show a considerable falling off in the total value of manufactured goods sent abroad, there seems to be a steady and uninterrupted spread in the popularity of what may be termed American novelties all over Europe. By the word 'novelties' are meant not only labor-saving implements and machinery to which most Europeans were strangers, but a great variety of articles of merchandise, such as boots and shoes, leather goods, hats and clothing, rubber goods, furniture and household utensils, hardware and cutlery, canned goods, glassware, clocks and watches, scientific apparatus, electrical supplies, and cotton, silk and woolen textiles—all of which possess distinguishing points of excellence and relative cheapness, new to Europe, which commend them to purchasers there in preference to similar articles of home manufacture. In other words, while the aggregate of our exports of manufactured goods has shrunk, the variety of our sales in Europe is being extended and the territory upon which they are encroaching is being steadily enlarged.

Advances in Austria-Hungary.

A striking example of this is seen in the case of Austria-Hungary, the country in which originated the idea of a European combination against American goods and where the hostility of the industrial forces continues to be most pronounced. Notwithstanding this, the imports from the United States, according to Consul-General Hearst, of Vienna,† are increasing rapidly, although American exporters have not until recently given general attention to that part of Europe, 'which is considerably removed from ports in closest touch with trans-Atlantic commerce.' So formidable is the growth of American imports, in fact, that 'Austrian manufacturers and agriculturists are making

* Extract from the 'Review of the World's Commerce,' introductory to 'Commercial Relations of the United States, 1901' (in press).

† See 'Advance Sheets of Consular Reports,' No. 1193 (November 19, 1901).

an organized effort to stem the inflow.' At a recent conference in Vienna to take measures against American competition, adds Mr. Hurst, 'it was openly acknowledged that the commercial policy of the present time is dictated and controlled by the United States. . . . Instances of the gigantic strides of our American manufacturing industries are cited to show our capability to forge ahead of all competitors in many fields.'

Still Leading in Germany.

In a report upon the commerce and industries of Germany,* Consul-General Mason, of Berlin, says the United States again heads the list of countries selling to that country, with a total of nearly $243,000,000, or 16.9 per cent. of the entire bulk of German imports, although it should be noted that this covers the values of all American products landed on German soil, 'a large percentage of which simply pass through . . . en route to Russia, Austria-Hungary, Switzerland, and Scandinavia.' It may be expected that later returns will show a falling off in German imports, owing to the recent industrial depression which has seriously impaired the purchasing power of the Empire. But in Germany, as in Austria-Hungary, our goods continue to hold their own, and the 'overshadowing competition of the United States' is regarded by German economists as of grave importance to the future of German industry and commerce. "It is recognized by intelligent Germans," adds Mr. Mason, "that in future industrial and trade competitions, that fine composite product of American racial qualities, institutions, and methods, the workingman who thinks, will, in combination with our unequaled resources, turn the scale in favor of the United States."

Supplying Europe with Goods we used to Import.

The same concern is felt in France, in Belgium, in Switzerland, in Great Britain—in other words, in all of the highly developed manufacturing countries of Europe—and it is a most significant fact that even in specialties which were once thought to be exclusively their own, the United States is becoming a more and more formidable competitor. Who would have imagined a few years ago that we would make such rapid progress in the manufacture of silk that we would soon cease buying silks from France, with the exception of highly finished goods, and would actually be exporting silks to that country? Yet this is what has happened. So of tin plate in Wales. At one time it was doubtful whether we could manufacture tin plate profitably, and it was confidently asserted that the Welsh must always control the Ameri-

* Printed in 'Advance Sheets of Consular Reports,' No. 1185 (November 9, 1901).

can trade. But we now manufacture all the tin plate we need, and the Welsh have recently imported tin bars from us.

There are, indeed, surprisingly few of the articles which used to be obtained exclusively abroad that are not now produced in the United States. The woolen as well as the silk industry of France and the hosiery industry of Germany are said to be suffering severely from our competition, and the Bohemian glass industry is feeling the effect of the increase of glass manufacture in the United States. Our cottons are steadily gaining in taste and finish, and are now sold in England in competition with the Manchester product. Says the Leipziger *Tageblatt* of April 10, 1901: "Even in fancy articles, in which the European market has set the styles for the entire world, the American manufacturers are beginning to compete with the European. British calico prints are also already receiving competition from America. As we hear, travelers of a well-known American house have offered American cotton stuffs in England with much success, and the London authorities declare them to be tasteful and worth their price." A New York company manufacturing cotton stuffs intends to found a Paris house which shall introduce its fancy woven stuffs for women's dresses, and trimmed women's hats are being exported from the United States to Europe. "The reversible cloths which are made in the United States," said Consul Sawter, of Glauchau, in a report sent in 1900, "are now the style in high-priced goods in the German capital." In agriculture, as in manufactures, we are constantly widening the sphere of our production. The orange and lemon growers of southern Europe are feeling the effect of California's competition. "It is ridiculous," says a Spanish newspaper,* "to think that fruits and vegetables raised on the slopes of the distant Pacific should compete at the very doors of Spain with those produced in this country. . . . Shall we live to see American oranges on the Valencia market itself?" We are producing our own raisins, our prunes, our wines, our olive oil, and are sending them abroad. California prunes now compete in Europe with Bosnian prunes, once a staple export to New York.

In the busy manufacturing district of Liège, Belgium, according to the annual report of Consul Winslow, more American goods are consumed than ever before, in spite of business depression. Our sales in general, says Mr. Winslow, have doubled in the past three years, and it is now common to see articles marked 'Americaine' in the shop windows. Spanish journals complain that steel rails are imported from the United States, notwithstanding the production of iron is one of the important industries of Spain. Vice-Consul Wood, of Madrid, says our goods are to be seen everywhere, and include such American

* 'Advance Sheets,' No. 1043.

specialties as hair-clipping machines, dental supplies, typewriters, electric motors, etc.

Decline in Exports of Manufactures.

The people of Europe, it may be assumed, therefore, are not less but more favorably inclined to goods of American origin, and the falling off in our exports, so far as they are concerned, is to be attributed to temporary causes, such as business depression, reducing their purchasing power, with the natural result of falling prices, or to discrimination against our products. The reduction is also found to be due, in part, to the elimination of the Hawaiian Islands and Porto Rico from the Treasury tables of exports to foreign countries, and to trade conditions in the United States, such as those affecting the exports of copper, which have checked the outflow of manufactured goods.

The Treasury statement of imports and exports of the United States for the calendar year 1901 (subject to revision) shows that the total imports amounted to $880,421,056, an increase of $51,271,342 over the year 1900; and that the total exports were $1,465,380,919, a falling oft of $12,565,194 compared with the previous year. The exports of manufactures amounted to $395,144,030, against $441,-406,942 during the same period of 1900—a falling off of $46,262,912. The percentage of manufactures in the total of exports declined from 30.38 in 1900 to 27.48 in 1901. On the other hand, the exports of agricultural products rose in value from $904,655,411 in 1900 to $940,246,488 in 1901—a gain of $35,591,077, thus largely offsetting the loss in manufactures. The percentage increased from 62.26 to 65.38. The decline in the exports of copper, not including ore, amounted to $24,007,711; and in manufactures of iron and steel, to $27,093,683.

Has Expansion been checked?

Notwithstanding the continued spread of our goods in Europe, and the deductions to be made from the Treasury figures on the score of accidental or natural causes of decline in manufactured exports, it is evident that the 'American invasion' of Europe has ceased, for the time being, to be of the sweeping character that distinguished it at first as an economic phenomenon. Our advantages in industrial competition in the abundance and cheapness of raw material and fuel, in the superior efficiency of our skilled labor, in the unexampled fecundity of our people in the invention of labor-saving machinery, and the advances we are constantly making in economies of production are still the subject of much anxious speculation in the great industrial centers of Europe; but there are some foreign observers who are encouraged by recent developments to hope that conditions may be more

nearly equalized by the substitution of new processes and improved machinery modeled on our own and the adoption of legislative measures aimed especially at our goods. It was pointed out in the 'Review of the World's Commerce' a year ago* that, in the reports of the consular officers for 1900, there ran 'along with a common note of satisfaction, a warning, here and there, of a more strenuous competition, which, in the end, may counterbalance our superior advantages to a considerable extent and check our progress in the world's markets, unless we equip ourselves in the meantime for the ultimate phases of the struggle.' As yet, it cannot be said that Europe has made any sensible progress, in actual performance, toward more strenuous competition. The measures adopted thus far are almost wholly tentative or preparatory, and it may be that those which involve restrictive legislation will be abandoned if the United States should consent to modify its tariff policy and permit the importation of a larger volume of European goods in return for similar concessions.

An English View of American Competition.

Upon the other hand, the decline in our exports of manufactures is taken in some quarters to indicate a subsidence in the aggressiveness and force of our competition. The London *Times* of January 7, 1902, in a careful review of our material progress in 1901, inclines to the view that we may have reached 'the top of the wave of commercial prosperity' and that the danger apprehended from the United States of 'aggressive economic interference with other countries' is not so serious as it was generally thought to be in the earlier stages of our expansion. Great as has been the real commercial and industrial success of the United States during the last two or three years, says the *Times,* "we are convinced that it is insufficient to warrant the view of its economic results taken either by sanguine Americans or by timid Europeans. The United States are not, as many Americans and some foreigners seem to imagine, exempt from the laws of nature. There are people who are so fascinated by great relative magnitude that they are unable to distinguish between it and infinity. Their judgment becomes, so to speak, polarized by the too intense contemplation of great but variable economic forces, just as a compass needle is disturbed by the proximity of a relatively large mass of iron, and their minds become incapable of receiving impressions from evidence that the really permanent economic forces are not dead or even sleeping. Now, there have been several pieces of evidence during the past year that the economic situation in the United States is not altogether so good as it appears to those who merely look at and discuss the surface,

* 'Review of the World's Commerce for 1900.'

whether from habit or because they have reasons for not wishing the public to look any deeper." In support of its assertions, the *Times* endeavors to show that the continued expansion of traffic receipts of American railroads loses much of its apparent significance when the fact is considered that it is not a new thing, but 'had been going on for a long time before the end of 1900'; that the sanguine prediction that, in a very few years, New York would be the monetary center of the world, based upon the theory that the United States was becoming a creditor instead of a debtor nation and was lending money to Europe instead of borrowing, is not being realized; that 'America has gone, for the time being, quite as far in the direction of employing her resources and credit as is safe, and possibly a little farther'; and that "the American public has never recovered from the fright it got in May last, in spite of every endeavor on the part of the leaders of the business world to allay the apprehension created by the panic, and to encourage a belief in the strength of the bond which 'community of interest' was supposed to have established among the able and ambitious men who govern the great business corporations of the United States."

Our Industrial Efficiency Undiminished.

Whatever be the force of these conclusions, they do not necessarily detract from the efficiency of the United States as a competitive force in the world's markets, for they do not in any way affect the advantages peculiar to us as an industrial nation, and if they did, they would be offset by drawbacks such as insufficient supplies of raw material and fuel under which the other manufacturing countries must, in the very nature of things, continue to labor. Moreover, it will probably be a long time before the conservative, slow-moving industrial forces of Europe will adapt themselves to the novel requirements which American ingenuity and enterprise have created. Both labor and capital in Europe would seem to have a long and difficult task ahead of them before they shall have approximated to the economics of production which we have mastered.

Alleged Obstruction by British Labor.

The labor conditions in Great Britain especially appear to be such as to seriously embarrass progress there and to give us a broader margin of opportunity in more quickly and more economically meeting the demands of foreign consumers. In a series of articles entitled 'The Crisis in British Industry,' a writer in the London *Times* asserts that the English trades-unions have so hedged about the productive forces of the Kingdom as to greatly diminish output and delay the execution of work. "Thirty years ago, our correspondent states, and we believe accurately," says the *Times* editorially, "a bricklayer

would lay 1,000 or 1,200 bricks in a day. In America, we are given to understand, the figure is even higher. Now, by an unwritten but mercilessly enforced trades-union law, a man must not lay more than 400, and if he works for the London County Council—that is to say, for the ratepayers—he must not lay more than 330. Our correspondent quotes a case of a building put up for the school board in which the average output of the bricklayers was 70 bricks a day. Yet these are men receiving the highest current rate of wages, a rate very greatly in excess of what was paid when 1,000 bricks were laid per day. This is typical of what goes on in every trade, though it may not always be so easy to give exact figures."

The United States consul at Liverpool, Mr. Boyle, in his annual report for 1901,* gives a most interesting description of the lengths to which this restrictive policy is carried. "The charge is made," he says, "that there is a general disposition on the part of British workingmen to obstruct as much as possible the use of labor-saving machinery, and to limit its output whenever the employers add machinery to their plant; and also that, in certain trades, the rule is 'one man, one machine,' whereas in America one man will attend to two or three machines. It is furthermore charged that there is an increasing disposition on the part of British workingmen to shirk work, and to use all expedients to perform as little labor as possible during the hours for which they are paid. These charges are made with great particularity against trades-unionists. There is, it is to be noted, a growing tendency throughout the country to shorten the hours of labor, while at the same time there is an upward movement in wages. As a rule, trades-unionists deny the charge of obstructing the use of labor-saving machinery and limiting the output; and they retort that employers are lacking in enterprise in not fitting up their factories with up-to-date plants. It is undoubtedly true, however, that, speaking generally and quite apart from the question of trades-unionism, English manufacturers find it almost impossible to get the same amount of product from machines as is obtained in America. There are two reasons that account for this, independent of any agreement, expressed or implied, on the part of trades-unionists to limit the output. The first reason is that, as a rule, the British workman is not as adaptable as the American workman—he does not so readily get command of new appliances as the American workman; and the second is that it is not the custom of the country for an Englishman, whether mechanic, clerk or laborer, to work as hard as an American." In Consul Boyle's opinion, 'trades-unionism has an influence in England far beyond what it has in the United States'; but he adds: 'It is but just to say that there is greater

* See 'Advance Sheets of Consular Reports,' No. 1222 (December 24, 1901).

need of trades-unions in this country than in America. Undoubtedly, English trades-unions have brought about great reforms in the condition of factories, as to the hours of labor, in regard to the employment of children, etc.; and there are indications that the alleged restrictive policy of trades-unions, express or implied, is gradually being modified."

American Workingmen promoting Expansion.

Whatever be the merits of the points at issue between employers and organized labor, it is evident that the existing conditions are not only unfavorable to the increase of Great Britain's competitive energy, but actually handicap her in the effort to adapt herself to the industrial exigencies which we have created. The advantage we enjoy in this particular is rendered all the more formidable from what seems to be a growing tendency in the United States toward a more harmonious cooperation between labor and capital, as was strikingly shown in the recent conference of employers and labor leaders in New York which resulted in the creation of a permanent board of conciliation. American workingmen generally, instead of seeking to limit output, strive to increase it, and they find their reward in the cheapening of production, which enables the manufacturer to compete in foreign markets and thus get rid of the surplus beyond the demands of home consumption, with the result of keeping his factory going and giving steady employment to the operatives throughout the year.

Competitive Energy but partly developed.

It may be assumed that, whatever the symptoms of a falling off in our sales abroad, the causes are not to be found in any decline of our industrial efficiency or in a more strenuous competition on the part of Europe. It is evident, however, that, if we would again attain the rate of progress of a year ago and keep it against all comers, we must avail ourselves of something more than the indigenous resources that have been described. As yet, we can not be said to have made full use of our powers. It must not be forgotten that, as has frequently been pointed out, our sudden and surprising success in invading Europe with manufactured goods was due, not to concerted and systematic effort on our part, but to the need of finding outlets for surplus product and the unlooked for recognition by European purchasers of the superiority of many articles of American manufacture. To a very great extent, our goods have sold themselves in the European markets, and that, too, in the face of high tariffs, of the hostility of industrial interests, and of a very general indisposition on the part of our manufacturers to adapt their styles, patterns, etc., to the tastes or prejudices of foreign consumers.

Necessary Aids to Future Growth.

It may be said, indeed, that we have hardly more than entered upon a novitiate in fitting ourselves for international competition. The establishment of sample warehouses and agencies at important trade centers, the employment of commercial travelers conversant with the language, customs, trade usages of particular countries; the development of adequate banking and transportation facilities; the adoption of proper methods of packing; the offering of more liberal credits —these are some of the conditions of the full utilization of our opportunities in foreign markets. If to these is added provision for a larger volume of exchange with countries which, to a greater or less extent, are now excluded from our markets, the real strength of our competitive powers will be developed.

Increasing Popular Interest in Foreign Trade.

It is encouraging to note that the people of the United States are becoming more and more sensible of the value of foreign trade and the importance of intelligent and well-directed efforts for its expansion. The growth of popular comprehension and approval is illustrated not only by the establishment of commercial museums, the organization of export associations, the demand for the creation of a separate department of the Federal Government having special charge of industry and commerce, and for the improvement of the consular service as an agency of commercial expansion, but also by the fact that our educational institutions, one after another, are rapidly adopting commercial instruction as an important feature of their work. Even the ordinary high schools are engrafting commercial geography upon their courses, and during the past year, the Bureau of Foreign Commerce has received applications from teachers and scholars in many parts of the country for copies of monthly and other consular reports as aids in this branch of study. The requests for information as to trade conditions in foreign countries from manufacturers and exporters have multiplied rapidly, and it may now be said that there is hardly an important business concern in the United States having a present or prospective interest in foreign trade which does not avail itself of the data furnished by the consular service.

Conditions in Undeveloped Markets.

The relation of the economic forces of the United States to those of Europe may be taken as the surest index to the probable future of our trade with the rest of the world; for it must be evident that, if we can continue to compete with European industries in their home markets, we shall have but little to fear from their rivalry in the neutral or undeveloped markets, where we would meet them on an equal footing.

Even in Canada, notwithstanding a preferential tariff of 33⅓ per cent. in favor of British imports, we continue, says Consul-General Bittinger, of Montreal, to enjoy 'more of Canadian customs than the rest of the world put together,' and many classes of goods which some years ago were bought in Great Britain are now more cheaply and more conveniently purchased in the United States. Last year, our sales to Canada amounted to more than $110,000,000, while those of Great Britain were only about $43,000,000. In Mexico, Consul General Barlow reports, the purchases from the United States show a large increase—over $4,000,000, or 11.8 per cent—while those from every other country exporting largely to Mexico, except Germany, show a large decrease. The German gain was only about $411,000, or 5.8 per cent. In the reports from Central America and South America, there are gratifying indications of substantial growth in the sales of our goods, and we are steadily widening the variety of our exports to Africa, Asia, Australasia—in other words, to every part of the world.

Commercial Work of Consular Officers.

In the 'Review of the World's Commerce' introductory to the annual reports for 1901* the effort has been made to summarize the detailed reports of the consular officers in such a way as to bring out the points of chief interest as to the trade and industries of the various countries and the obstacles to, as well as the opportunities for, the sale of American goods. It is but due to the consular officers to add that the quality of their work shows continued improvement, and that, thanks to their industry and promptitude, the Department is again enabled to transmit the annual reports to Congress within a month after the close of the calendar year.

* 'Commercial Relations of the United States' (in press).

THE SOIL AS AN ECONOMIC AND SOCIAL FACTOR.

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THERE is no part of the material world about us that is more intimately connected with the general welfare of the people than the soil. It has often been said, and well said, that it is the foundation of agriculture, in more senses than one. And the importance of agriculture in our present social systems is too well understood to justify any further comment here.

For practically a century the study of soils, and the phenomena they present, has received the attention of some of the ablest and most distinguished savants the ranks of science have held. Much is now known about soils from the point of view of the geologist, the physicist, the chemist and the bacteriologist. Much more is yet to be learned, and this perhaps is not the least interesting feature of the subject to one of a philosophic or scientific turn of mind. But when the geologist, the physicist, the chemist and the bacteriologist have brought together all the data and material of which they are capable, and have presented it to the world in accessible form, it is evident that but a very small part of the study of soils has been accomplished, or can be accomplished, by them.

It is necessary, as this paper will endeavor to show, that upon the labors of those investigators who have worked from the point of view of the natural sciences, the economist and the sociologist must build for the best development and use of the soil. They seem, up to the present, to have given very little attention to the subject, and the general knowledge of it seems to be summed up in the saying—'A poor soil, a poor people; a rich soil, a rich people.' This aphorism is in fact the immediate text of this paper. It implies what is apparently self-evident—that the soil is an economic factor because upon its character and the treatment of it depends the success of agricultural operations; and it is a social factor because the character of the soil in a very large measure determines the character of the people living upon it. The causal connection between the typical Yankee's well-known characteristics and his peculiar soils and environments has become almost classical in our literature. That which exists between some of the poor white communities in our Southern States and their soils is even more obvious. And just as striking are the opposite conditions on some of the rich limestone soils of our eastern states, or some of the intensely cultivated, rich, irrigated districts of the west.

Like all popular sayings, this one contains much truth. But it is sometimes untrue or at least misleading. For whether or not the soil be poor will depend entirely upon the point of view, and that there may be at least more than one point of view for any given soil will, it is believed, become evident from the following pages. Soils which are seemingly poor, and supporting but a poor population, may be in fact, or at least potentially, quite rich. But in order to make plain what is meant, it will be well to point out briefly some of the facts that are now known, and some of the views that are held by those who are making an especial study of soils. It will not be necessary to go into very much detail, for it will be sufficient to present the leading ideas in a general way in order to show that the work of the physical scientist touches, as a necessary consequence, both the field of economics and sociology. From these points of contact the effort will be made to indicate a few at least of the social and economic possibilities which a study of the soil presents, and to submit a plea that those to whom we look as leaders in these latter directions will find this subject of such importance and of so much interest that they will be impelled to do something towards the development of this side of it for the benefit of our country and possibly mankind at large. It would seem, as indicated above, that an almost virgin field for investigation is offered here, which can hardly fail to yield rich rewards to the student.

The soil is a very complex, heterogeneous mixture, or as one may say technically, material system. It is composed of three distinct parts or phases: First, the mineral and organic matters in a solid condition; second, the water, or water solution, which all soils contain; and third, the gaseous part, which fills the interstitial spaces between the solid components of the soil not occupied by the ground solutions. Furthermore, the soil is in contact with the atmosphere above it. It is probably from the ground solutions alone, or almost entirely alone, that the plants take their nutriment as far as the soil itself is concerned. Of course it is perfectly well known that the carbon and oxygen, which form so large a part of the plant tissues, are obtained mainly from the atmosphere above the soil and in contact with it. But the plant can derive its mineral foods from the soil solution only, and it is upon the concentration and composition of the solution that the well-being of the plant is primarily dependent. The nature of this soil solution is in turn dependent both upon the nature of the solid and of the gaseous components of the soil. Furthermore, it is intimately connected with the physical conditions of the soil—that is to say, with its texture, or the size of the solid particles, and the structure, or the arrangement of the particles, mainly because upon these factors depends the amount of water which the soil will hold under any given conditions of temperature, climate, etc. And upon the amount of water which it will hold

will depend in turn the composition and nature of the soil solution. The soil, then, is composed of something more than the solid components alone, and this point of view is well worth accentuating, because it is not always recognized, and because upon it is dependent much of the modern development in soil studies.

The solid components of the soil are derived from two general sources. The mineral components are derived from the decomposition of the subsoil, or the underlying rocks. Or at least from rocks, although perhaps at some distance, when the soil has been carried to its present position by water, wind or other like agencies. Besides these mineral components of the soil, there are always more or less detritus and organic remains from the decomposition and breaking down of organic tissues from the present and former vegetation.

It is true that some of the components of the soil are so very little soluble as to be called in popular language insoluble. But there is, in reality, no such thing as an insoluble substance, and even those components of the soil which most nearly approach this condition are, to some extent at least, soluble in the ground water. And it is from these slightly soluble minerals and organic substances that the ground solution obtains its dissolved material, which serves in turn as food for the plant when presented in this available form. By the action of atmospheric agencies, oxidation, etc., by the solvent action of the water, by the action of dissolved gases, such as carbon dioxide for instance, and by the action of numerous microorganisms which exist in practically all soils, both the mineral and organic matters are broken down, decomposed, and part of them made more soluble. This is essentially the process known as weathering, and it is going on all the time. It may be checked, or it may be augmented, but it cannot be stopped entirely. It is nature's method for bringing the mineral nutriments in the soil into such forms as to be 'available' for plant nourishment, in contradistinction to that potential plant food which is present, but in such forms as to be unavailable. The distinction between available and non-available plant food, while now sufficiently obvious, was not recognized in the earlier studies, and marks in fact one of the first great steps forward in soil investigations.

Plants do not take from the soil solution the various dissolved substances which it contains in the same relative proportions in which they are present. Therefore by the continued growth of a particular kind of crop, and its periodic removal by cropping, it may happen that some one or more of the necessary plant nutrients in the soil may be removed more rapidly than others or than the normal weathering of the soil can furnish it to the soil solution. If this process is continued far enough, the plants fail to thrive and the soil becomes barren, or, as it is popularly phrased, exhausted. Much that is incorrect is

popularly believed on this subject of exhaustion. There is probably no such thing, in a strict interpretation of the term, as an exhausted soil, for it is pretty thoroughly established that although a condition of the soil may have been brought about, as just described, in which it is not suited to the growth of a particular crop, it may be very well suited indeed to some other crop, and generally is suited to some other crop, and so the term 'exhaustion' in this sense is really a relative one only. It has likewise been pretty thoroughly established now that plants, like animals, need a varied, and, as it is sometimes called, 'balanced' ration; that there is a particular combination or proportion of various constituents in the nutrients which is best adapted to a plant at any particular stage of its growth. For example, it is well understood that for the development of a grain crop, especially at the time when the grain is forming, a certain amount of magnesia is necessary. But if the ratio of the magnesia to the other necessary mineral elements is above a certain figure, the soil solutions become extremely toxic, with the results that the crops fail and the soil is barren. It has been found that the absolute amount of the magnesia which may be present and probably causing the barrenness of a given area is extremely small—so small, indeed, as to be difficult of accurate estimation. But if the ratio of other elements to the magnesia, for instance lime, be raised sufficiently high, the plants will do remarkably well, and, up to a certain limit, the more magnesia, the better they will do, so long as the ratio of the magnesia to the lime does not become too high. These views will explain what was meant when it was said above that the fertility or non-fertility of the soil is relative, and it is as a matter of fact, the explanation of the earlier remark that the expression 'a poor soil, a poor people, etc.,' may be misleading, if not positively untrue. For it is very probable that there is no soil which is cultivatable at all which could not be regarded as a fertile soil for some crop.

It is possible to modify the conditions as to the fertility in any given soil by *tillage,* which changes the physical condition of the soil and removes interfering growth from the crop we wish to cultivate; which, on the one hand, promotes capillary rise of water from the lower depths of the soil, or, on the other hand, cuts it off from the surface to prevent its too rapid escape; and which may improve the physical condition of the soil and further promote the natural rate of decomposition or weathering. Again it has been found in modern times that the *rotation of crops,* or change of crops, will aid the soil. And the reason for this probably lies in large part in the fact, as noted before, that one crop requires a different proportion of constituents in the soil from another, and if it is changed in the proportions of the constituents present, it is still adapted to the succeeding crop, giving time for those which became deficient through the growth of the first crop, to be again

accumulated in sufficient quantity and relative proportion. Other factors enter of course into rotation, such as change of the texture of the soil produced by one crop making it better for another, the elimination of parasites, etc.

A third method is that of *fertilizing,* and a most complex group of phenomena is involved in this practice. The function of fertilizing is probably three-fold at least. The added material may change the texture, structure or other physical conditions of the soil, whether it be by mechanical mixture or by some other physical or physico-chemical process, such as is probably involved in the flocculation of clays by certain solutions. Its most obvious purpose, and the one which is the controlling idea among agriculturists at large, and perhaps to entirely too great an extent among the supposed scientific workers in this field, is the direct addition of plant food to the soil. It is not intended by this latter statement to minimize the importance of this function of fertilizers, but to insist in the most emphatic way that more attention should be given to the third function, that is—the changes in the solubility of the soil components already present induced by the addition of fertilizing materials, especially the so-called mineral fertilizers or salts. This is not the place for, nor would the space allotted to this paper permit of, a satisfactory discussion of the subject. Suffice it to say, for the present, that it is thoroughly well known, though not always generally recognized, that great changes in the solubility of the soil components already present may be brought about by the addition of foreign material, and in this sense the process of fertilizing is one of retarding or expediting the natural weathering of the soil components originally present.

Within the last few years, it has come to be recognized that bacteria or other microorganisms play a large part in the fertility of arable soils; that the development of some of these is desirable, that of others, not. And while this side of the subject is in hardly more than the preliminary stages of its development, yet a good deal is known as to the several conditions which make for the presence of the desirable organisms or *vice versa,* and these conditions are for the most part readily controlled. Furthermore, the point has been reached when we can actually inoculate the soil with desirable substances of this nature. There is no branch of soil study which is offering greater promise of advancement at the present time than this. And the opportunities it offers for increasing our control over soil conditions augurs much for improved agricultural practices. Here again it seems worth while to call attention to the fact that these organisms are valuable not only for themselves, or rather the immediate products of their activities, but also quite as much probably for their influence upon the soil components already present, either in breaking them down into simpler forms or in

general in making them more soluble in the ground waters, and thus more available to plant nutrition.

It will thus be seen that it is possible to control, in a measure, the soil. In another way much has been done in controlling soil and soil conditions, and that is in controlling the climate above the soil. This climate, or condition of the atmosphere above the soil and in contact with it, is also a most important factor in the growth and development of plants, and any way in which this can be controlled, correspondingly can the development of the plants be controlled. This is familiar to every one in the use of frames, hot-houses and conservatories, and, in some of the modern structures of this kind, it can hardly be said that the method is one adapted to a small scale only. In illustration, attention might be called to an establishment in Rhode Island which has upwards of fourteen acres under glass for the cultivation of one crop alone. And this can hardly be regarded as an isolated instance. Many others as extensive, or perhaps even more extensive, might be cited. In the last few years an even more striking illustration, because much greater in extent, of this control of climate has been developed in this country. For this purpose as well as for some other reasons, enormous areas in Florida are covered with either slats or cloth tent-like arrangements. These are erected for the purpose of protecting the plants and developing abnormal or unusual growth in certain varieties of tobacco, and have proved immensely successful in prolonging the growing season, through a modification of the climate about the plant, keeping it moist and warm, not cutting off the light entirely, but partially, and preventing the great evaporation from the surface which would dry the soil, and hasten the ripening of the plant. The experiment has been repeated in Connecticut under the auspices of the Bureau of Soils, U. S. Department of Agriculture, in cooperation with the Connecticut Experiment Station, over a very considerable area, sometimes single fields of as much as eight acres in extent being now protected by these cloth coverings for the production of a high-grade wrapper leaf tobacco. The shading of one crop by another with a taller, umbrageous growth, is a similar procedure. And this is practiced quite extensively in some places, as in the shading of coffee trees by larger tree growths, or the more familiar nurse crops, common in some parts of the United States. Modifications of the climate in other ways, by planting of trees, erection of wind brakes, and devices of a similar nature, have been used with greater or less success in certain regions, and are all more or less well known.

It is thus possible to greatly modify the soil and the soil conditions. Nevertheless the fact remains that it is impossible to make one soil just like any other soil. Consequently characteristic differences do exist in them, and it follows that some soils are adapted to some purposes for

which other soils, which are in themselves very good, are totally unsuitable. And this leads at once to the idea of the adaptation of special crops to special soils.

In a general way it has long been recognized that certain soils are unusually well adapted to the production of particular crops, as the celery soils of Kalamazoo, the wheat soils of the Red River valley, etc. But it is not generally recognized that each particular individual soil is best adapted to some particular crop or rotation of crops, and perhaps the greatest economic sin of the farmers of this country has been the almost general refusal to appreciate this cardinal, fundamental truth. Much improvement in this direction is to be noted within the last few years. It has come to be more and more recognized that at least some soils are more profitable when confined to the production of particular crops, as with the lettuce soils about Boston, the soils of the apple belt through the middle Western States, the soils of the sugar-beet areas, the sandy truck soils of the Atlantic seaboard, all coming into prominence for the particular crops cited.

Something more than merely empirical determinations on this subject can now be recorded; and perhaps the most striking illustration is a development of certain soils in the Connecticut Valley, which soils were generally regarded as very poor and practically valueless, until it was pointed out as the result of the soil survey of the Connecticut Valley by the Bureau of Soils, U. S. Department of Agriculture, that these very soils were markedly similar to those of Florida, on which the best Sumatra seed tobaccos were grown. The climate of the Connecticut Valley during the growing season is not very different from that of Florida, and by the use of the tent-like arrangements for shading, to which reference was made above, climatic conditions over the soils in both Connecticut and Florida can be made very similar indeed. This has actually been done, and there is now being grown in the Connecticut Valley a fine grade of cigar wrapper, which apparently equals in every respect the best product of Florida or of the Island of Sumatra itself. This is but one of the most striking of several similar developments for particular types of soil to which attention might be directed, where the possibilities have clearly been seen, before the introduction of a crop or dependent industry. Many thousands of dollars have thus been brought to the producers, and this, than which there could be no greater, is a powerful economic argument for the liberal support of soil studies on a broad, but systematic, basis.

With this idea of the adaptation of particular soils to particular crops, it becomes evident at once that the classification of the agricultural soils is not only desirable, but a fundamental necessity for the thorough scientific study of the soils of the country. This necessity is now so well recognized that the national government

is supporting a large and growing bureau in the Department of Agriculture for the classifying and mapping of the soils in the principal agricultural areas, supporting these surveys with strong laboratories for the investigation of soil phenomena, its management and economic control. More interesting to note, is the growth of this work with some of the individual states which, either in cooperation with the surveys of the national government or individually, are now annually expending many thousands of dollars in this direction, with the firm conviction that in no other way could a surer investment be secured for ultimate large returns. But the work upon soils, thus hastily sketched, has been and is being done almost entirely upon the physical side. This has been, in the past, in accordance with the peculiar nature of the case. But there is another side, no less important, as difficult, possibly more difficult, to handle, giving justification for the title to this paper.

The results which are being obtained both by the national Department of Agriculture, by the many experiment stations, and other agricultural institutions connected with the American universities, are being freely disseminated among the people, and the major part of the results obtained abroad, not only in England, Germany and France, but in Russia, Sweden, Norway, Holland, Japan and elsewhere, are available to any intelligent farmer in this country who cares to take a little trouble and pains to obtain them. This being the case, the question naturally arises as to the reason why the practical agriculturists of this country make so little use of these results. For it is not to be doubted that the agricultural possibilities of the soils of the United States are very great—certainly much greater than has been realized thus far. The answer to this question is partly a psychological and wholly a sociological one. With some few exceptions, the farmers at large do not approach their occupation with the point of view connoted by the term 'business principles.' Perhaps this idea is best brought out in the yet current classification of man's occupations into the learned professions, farming and business. It is generally recognized by all professional men that their best success is obtained when the principles of business men are applied to their own affairs. As a matter of fact, what are usually called business principles are sound scientific methods. But this has not been recognized as yet by the main body of farmers in this country, and they seem to be actuated in the management of their farms largely by sentiment, much as some men take their religion or their politics, because their fathers managed in this way, therefore that is the way in which they should manage. Their forebears did well, under vastly different conditions and standards than those which obtain to-day, and the obvious fact that the descendants are not doing so well is met with all manner of explanations and excuses, which, just as obviously, have little or nothing to do with

the case. Instead of studying a soil and its situation, and determining to what crop, or rotation of crops, it may be best adapted, the farmer continues to cultivate the same crops his predecessors grew, or he puts in one he may happen to wish for some fancied reason, possibly in some cases caprice. For example, a man may wish a grass farm, and instead of studying his soils to determine if they be adapted to this purpose, he may sink hundreds of dollars in a vain attempt, foreordained necessarily to failure, which might have been as surely foreseen. A good illustration is the tobacco crop in southern Maryland. In many ways, it is a fine crop to grow, making an attractive, handsome appearance in the field, pleasing to one's esthetic sense. Moreover, it has been grown in this region from time immemorial. But for various reasons, it can no longer compete successfully with tobaccos from some other regions, and now brings but very little money. Nevertheless, the people are accustomed to this crop, they like its cultivation, and consequently it remains a staple, although it is very well known that the soils devoted to it are much better adapted to certain other crops which would indubitably yield a vastly greater money return.

Over the wider areas of our country this seems to be about the spirit in which agricultural conditions are still viewed and met. Where intensive agriculture is practised, as in the truck soils, or in the irrigated soils of the West, this is not the case, or not so frequently the case, and can never be where intensive methods are practised, for it is a necessary corollary of the high prices which lands under the intensive system of cultivation command, that the crops for which they are best adapted must be raised, or absolute failure inevitably follows. But where the extensive methods of cultivation are practised, it is usually possible to drift along on half crops or third crops, and still keep matters going on a gradual decline until conditions are so bad that the land is abandoned as barren, and pastures new are sought elsewhere.

While the soil may be best adapted to some particular crop or rotation, other conditions enter, or may make it more desirable to substitute a different crop or rotation not so well suited. For questions of transportation, or supply and demand, and of available labor, inevitably enter into the business management of every farmer, and thus the soil is an economic factor in every community. In certain areas of Arizona, for instance, the soils, climatic conditions and general features indicate most strongly the advisability of raising fruits. But the transportation facilities up to the present have been so unsatisfactory that it has been impossible for the Arizona horticulturists, even with earlier crops than California, to put their products on the Eastern markets at such figures as to compete satisfactorily with those from the latter state. Again a case comes to mind of a plantation in eastern North Carolina, with an unusually fine crop of peanuts, covering about 400

acres, at a time when the market was in a remarkably satisfactory condition. Yet this crop was a complete and disastrous failure because the unreliable labor conditions existing in that locality prevented the proprietor from securing more than a quarter of his crop, the greater part of it remaining on the ground to rot or to be devoured by birds, etc. Thus it is that the management of the soil, as in every other practical policy in this world, must be largely a give-and-take matter, or a question of double-entry bookkeeping, so to speak, and manifold considerations are involved. Where one gains in one way, he loses in another, and it is sound judgment or business sense which will determine what is the best thing to be done in any given case to get the most out of the soil under the conditions surrounding it.

Opportunities to get just such training as is necessary for the intelligent management of the soil are readily accessible in this country. Agricultural colleges and other colleges not professedly so, but giving courses in agriculture, both on the theoretical and on the practical side, are numerous. The necessary expense of attending them is certainly not great, and well within the means of a very large number of the youth in the rural districts. But it is an astonishing fact that they are not availed of, astonishing because to one of a philosophical or scientific cast of mind, there are few, if any, fields more interesting, or better adapted to the practical application of scientific methods than those of agriculture, and especially of soil management. Yet in our so-called schools of agriculture and mechanic arts it is indeed unusual when the number of students, presumably farmers' sons, who graduate in the mechanical arts as engineers, surveyors, etc., do not largely outnumber the students taking their degree in the strictly agricultural courses. This is even more astonishing when we reflect that there is a demand, and a growing demand, in this country for skilled agriculturists to manage the estates either of rich individuals or of corporations, and the development of special crops for special industries. The demand for men of this description is at the present time greater than the supply, and such as have the proper training and qualifications can command salaries from $1,500 to $4,000 or $5,000 per year, possibly, in exceptional cases, much more. A case could be cited, where a fine house and grounds and $10,000 per year were offered to a certain expert to take charge of a large plantation devoted mainly to the production of a particular crop. These salaries are far above the average incomes of young men in other branches of professional life. The life is in other ways an attractive one; it requires more or less aptitude in the qualifications of the student, for, as in every other branch of professional life, the successful man is one that necessarily keeps up with modern developments along his line; but it must from the nature of the

case be largely an out-of-door life, and attractive to any one who has the least spark of the love of nature in his soul.

It would unquestionably be a most interesting and fruitful line of investigation for the sociologist to study the causes which are apparently diverting men from this most attractive field of labor. There are some popular conceptions upon this subject, we know. It is generally admitted that there is a tendency for men to congregate in the cities or the towns in preference to remaining in the country, and various reasons are assigned for it. We hear much in this connection of the gregarious instinct of man, but this is hardly a sufficient reason. For the entire trend of modern scientific agriculture is towards intensive cultivation, and the gregarious instinct should be sufficiently gratified in populations where this method prevails. On the other hand, it is sometimes held that the chances for development in a social sense are greater in other professions or occupations, such as business life, and these are having their effect upon the youth of the country. This may be true to some extent, for it is as natural for man to prefer fine clothes as it is for birds to prefer fine feathers, and the accepted garb of the farmer is certainly not as attractive to mankind at large as the everyday costume of the physician, clergyman or clerk. But that it can be as potent as it is generally believed scarcely seems probable, unless one is to accept the notion that the farming class, speaking in a broad way, is no more intelligent than the class from which the average servant girl of the city comes.

The opportunities for the development of special lines in agriculture and soil management are certainly as great and should be as attractive as in other professions. There is as great an opportunity for the development of experts in sugar-beet-raising, apple-raising, rose-raising, as for the development of specialists in eye, ear and throat treatment, corporation law or criminal procedure, mechanical engineering or electrical engineering, etc., and with this unusual knowledge and unusual ability along specialized lines will come also the unusual pecuniary emoluments that are found in other professions.

Many problems of a sociological or economic nature suggest themselves in this connection, and it is certainly not from lack of subjects or material that the literature is nearly barren. But the object of this paper is to call attention to this subject, rather than to discuss it, which must be left for abler and better fitted pens. The development of new countries, as influenced by the soils, such as in the case of the westward movement from the tide-water regions of the Atlantic slope, along the limestone belt of Pennsylvania, Maryland, Virginia, Kentucky, Tennessee and Ohio; the differences which do, and must of necessity, exist between communities practising intensive or extensive methods of cultivation; the land-rich and money-poor man,

and his status in the community; whether it is advisable in the general interest of the state, to encourage the development of large or small farms; whether the methods in vogue in some other industries, the combinations of resources and capital sometimes developing into 'trusts' can be successfully adapted and applied to agricultural pursuits; the building up of infant agricultural industries, by government aid, or the extension of the principle of protection to agricultural productions, and dependent industries; whether, on the whole, it would be better to make for a complete specialization, or whether it would be more advisable for each farming community to raise its own necessities—these are but some of the problems which are directly connected with the soil and the soil management, and are also social and economic questions. It therefore seems appropriate to those of us who are interested in this study from the point of view of the natural sciences, or applied science, as it is the fashion to call it now-a-days, to enter a strong plea that our efforts should be seconded by a more serious attention to this same subject from the professional economist and sociologist.

THE DRAINING OF THE ZUIDER SEA.

By Professor J. H. Gore,
Columbian University.

'GOD made the world, but the Dutch made Holland' is a saying quite common with people who visit the Netherlands; and as one looks upon the great sea dykes that keep the North Sea from sweeping over North Holland or the smaller dykes that hold the rivers within their channels, it is easy to see that the retention of the land created is possible only with great vigilance and care. Lakes have been drained and their beds converted into arable land, useless bends have been taken from the rivers and the ground, once covered by marshes, has become fertile gardens. The map of Holland shows many changes, not only in the coast line, but in the water covered areas within.

The draining of the Haarlem Lake was looked upon as a marvel of engineering skill and patient industry, but the work here discussed is far greater in magnitude and presents technical and economic difficulties never before encountered.

A clause in the constitution of the United Netherlands permits the organization of new provinces. However, when it was written, there was in mind the possibility of rearranging the eleven provinces in such a way as to enlarge the number. The acquisition of territory of any considerable area was not thought of until 1848, when it was proposed to drain the Zuider Sea, which, if accomplished, would add a province somewhat larger than Zeeland.

In 1892, Queen Emma appointed a commission, consisting of the Minister of Water Affairs and twenty-nine members to consider the general question of converting this shallow inland sea into agricultural lands. Two years later, a very elaborate report was submitted, in which the problem was discussed from every conceivable standpoint. So many questions were raised in this report and so much discussion was provoked that it was not until last summer that the people generally realized what the Commission actually proposed and how the work was to be done. The air has been sufficiently cleared to enable one to assert that while it is universally conceded to be possible to drain as much of this sea as may be desired, there remains the feeling that while the cost of this undertaking is certain, the benefits are by no means sure.

It is proposed to build a sea dyke from Ewijksluis in North Holland over the island of Wieringen to the Frisian Coast near Piaam, a dis-

tance of 24.8 miles, the cost $16,000,000 and to require nine years to build.

This route was selected because it would be possible to construct the locks in the solid ground of the island and, though not the shortest line that could be selected, it would be in the shallowest water and so far south that some of the streams flowing into the sea would have their outlets outside of the district to be drained. Along the top of this dyke it is intended to have a railroad, thereby shortening the distance by rail from North Holland to Groningen by 35 miles—a matter of considerable importance in a country where no distances are great.

By shutting out the North Sea, the water left in the Zuider Sea would be fresh, and it was feared that this change would cause the death of the vegetation along the shores and that sickness would result from its decay. But the freshening process would be so gradual that there would be abundant opportunity for an adaptation of vegetation to the changing conditions. The entire scheme contemplates a step-by-step process. That is, after completing the sea dyke, so that the inflow of water can be stopped and the outflow regulated by the use of the sluice gates, it is proposed to surround in the northwest corner of the imprisoned sea about 52,620 acres and from this pump out the water. As fast as the land within this dyke should become free from water it would be subdivided by ditches like the rest of Holland and placed under cultivation at the earliest possible moment. It is believed that this can be done in five years and that the cost would be about $5,000,000.

The portion of the sea to be included in this, as well as in other polders, the name given to drained areas, has been determined from many thousand borings, and also from the desire to avoid stopping up or diverting any of the larger streams that now empty into the sea.

After putting this polder in good shape, the southeast corner will be dyked in and the water pumped out, yielding ultimately 249,000 acres. This will require ten years and the cost is estimated at $24,740,000. After this shall have been completed 77,800 acres will be enclosed in the southwestern section of the sea. The work of converting this into arable land will require four years, and cost $9,140,000. The last section to be drained will be in the northeast, where $125,649 acres will be added to the domain after five years' work at an estimated cost of $14,000,000.

The polders have been selected so as to leave undisturbed every important city now on the sea, and also to allow all the rivers to empty into the part of the sea not included. The plan also contemplates the deepening of the mouth of the Ysel, the broadening of the entrance to Amsterdam, and the improving of the outlets of all the rivers now emptying into the Zuider Sea, in this way bettering the condition of

all the harbors, placing the canals under better control and converting the remnants of the sea into a body of fresh water, so that in case of overflows the land will not be damaged as it is now.

By doing the work in this piecemeal fashion, covering thirty-three years, only 24,000 acres will be added annually. This can be brought under cultivation without causing any disturbance to agricultural conditions in the country or affecting the markets of foodstuffs. Then too, by the gradual draining of the sea the fishery interests will not be suddenly imperilled, and persons now engaged in fishing will have time to adjust themselves to the new conditions.

Heretofore the littoral rights have been the most difficult to adjust. The people realized that many of the cities of Holland have been 'built on herring bones,' that the fishing fleets were the schools in which so many Dutchmen had learned the sailors' trade, and that it was on the sea that Holland won her greatest victories of peace as well as of war. The Commission, therefore, made a close study of this question. They ascertained how much money is invested in the Zuider Sea fisheries, how many men are employed, and what the annual catch amounts to. They learned that the investment was less than had been surmised, that many of the fishermen spent only a small part of the time fishing and that acre for acre the egg sales in the Haarlem polder exceeded the fish caught from the Zuider Sea. However, it is understood that some must suffer in being obliged to change their mode of earning a livelihood, and provision is made for lending assistance. All persons having vessels large enough to engage in the North Sea fisheries are to be exempt from harbor dues when returning with a catch; all men over fifty-five years of age who are now devoting the greater part of their time to fishing will receive a pension, and the smaller craft will be purchased by the State.

When this new province becomes a part of the Union, it will be divided into districts of the most approved size, with ground reserved for schools, churches, cemeteries and town halls.

But it is not intended to sell the land thus acquired. The interest on first cost and the maintenance is all that is asked of the occupants who become perpetual lessees of the ground. This amounts to an annual tax of about $7 per acre. The rentors are to erect their own buildings and be subject to the usual rate of asssessment on all personal property. Inasmuch as land in the Y polder rents for twenty dollars per acre and some for even more, it is thought that the price here expected can be easily obtained.

Dividing up the sea by polders and building a sea dyke across its mouth will lessen the dangers from storms and overflows and diminish the cost of maintenance of the long dyke that now fringes the entire sea. By leaving open water between the polders where the deepest

water is now found, there will be no impeding of intercourse between the larger cities that now enjoy boat communication.

One would expect to see the financial features well considered. The Commission asks the State to pay annually $758,000 for 33 years, and to raise this amount by the issue of Zuider Sea bonds of 100 florins (about $40) each. These bonds to be sold in the open market or given in exchange for deposits in the Postal Savings Bank. The bonds are to yield 2.6 per cent. and be legal tender in payment for ground rent. No one sees any difficulty in this plan of procuring the means. Dutch credit is good and the State finances have been so well managed that since 1850 the public debt has decreased by an amount in excess of what is deemed necessary to carry out this great plan.

The plan is not only feasible from a financial as well as from a technical standpoint—it is almost a necessity to the State. At the present time only 56 per cent. of the land is cultivated by the owners, and the number of small farms—less than two acres, has increased at the rate of 2,072 per year during the past ten years. The demand for land is so great that rents are growing larger with the result that less surplus food stuff is available, and the people are therefore affected by the fluctuation in foreign markets. Then too the country is annually losing 5,000 of the strongest inhabitants who are forced from home in search of work.

In the immediate future a large proportion of these people could find work in the draining operations and, as the lands become available, the surplus population that must now seek homes in foreign lands, could find land in their own country and that, too, close to Amsterdam, its best market.

Holland has suffered more from storms on the inland waters and inundations therefrom than from the seas that skirt her coasts. The drying up of the Haarlem Lake removed one great source of danger and loss, but immunity will not come until the Zuider Sea, which has been a constant menace since 1440, yields her 787 square miles to the tillers of the soil.

The Dutchman is especially fitted for work of this sort. He calmly sits down, reckons up the cost of the undertaking, devises means and appliances and then proceeds with the work without troubling himself whether it will require one year or twenty. He does not expect to play the part of Canute and command the waters to recede, but ever conscious of the inroads that the sea has made upon his country, his work is sweetened perhaps by a feeling of revenge that he will reconquer all that has been lost and levy tribute for the 371 lives that were lost in 1885 by the breaking of some of the dykes.

The Government is willing to appropriate the requisite money just

as soon as the finances will permit and entrust the work to a contractor, knowing that every one of the 1,250,000 piles needed for the sea dyke alone will be put in place and that not a hundredweight of the 70,000 tons of basalt blocks will be missing. The Dutchman is so loyal and feels so much national pride that no imperfect work is ever found in Government contracts.

An idea of the magnitude of the work can be formed by glancing at a few figures.

The sea dyke will be 24.8 miles long, 114.5 feet across the top and 21.6 feet above high water; the river Ysel is to be carried out into the sea a distance of 10.5 miles with a width of 948 feet; the entrance to Amsterdam must be widened by two miles; dykes around the polders will be necessary having an aggregate length of 198 miles with an average height of 11.4 feet; in the Island of Wieringen, 30 locks will be required, 33 feet wide and 16 feet deep; an encircling canal must be constructed from Enkhuyzen to Uitdam, a distance of eight miles; the sea dykes on the Frisian coast must be heightened at a cost of $240,000 and four pumping stations with an aggregate of 16,930 horse power must be installed.

Though the undertaking is great, the entire commission agreed that it should be done, and twenty-one out of the twenty-eight believed that the State should be in control rather than to grant the concession to a private party. When finished the State can issue another medal, like the one minted to celebrate the draining of the Haarlem Lake to bear the inscription:

"Zuider Zee, after having for centuries assailed the surrounding fields, to enlarge itself by their destruction, conquered at last by the force of machinery, has returned to Holland its invaded land." And the historian of the work will close his account of the material gain to the State by saying: "But this is not all; we have driven forever from the bosom of our country a most dangerous enemy; we have at the same time augmented the means for defending our capital in time of war. We have conquered a province in a combat without tears and without blood, where science and genius took the place of generals, and where polder workmen were the worthy soldiers. Persevering to surmount the obstacles of nature, and those created by man, the country has accomplished, to its great honor and glory, one of the grandest enterprises of the age."

THE EVOLUTION OF FISHES.

By President DAVID STARR JORDAN,
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WHEN a fish dies he leaves no friends. His body is at once attacked by hundreds of creatures ranging from the one-celled protozoa and bacteria to individuals of his own species. His flesh is devoured, his bones are scattered, the gelatinous substance in them decays, and the phosphate of lime is in time dissolved in the water. For this reason few fishes of the millions who die each year leave any trace for future preservation. At the most, a few teeth, a fin spine or a bone buried in the clay might remain intact or in such condition as to be recognized.

But now and then it happens that a dead fish may fall in more fortunate conditions. On a sea bottom of fine clay the bones, or even the whole body, might be buried in such a way as to be sealed up and protected from total decomposition. The flesh would in any case disappear and leave no mark or at the most a mere cast of its surface. But the hard parts might persist, and now and then they do persist, the lime unchanged or else silicified or subjected to some other form of chemical substitution. Only the scales, the teeth, the bones, the spines and the fin rays can be preserved in the rocks of sea or lake bottom. In a few localities, as Green River in Wyoming, Monte Bolca in Tuscany and Mount Lebanon in Syria, with certain quarries in Scotland and lithographic stones in Germany, many skeletons of fishes have been found, pressed flat in layers of very fine rock, their structures traced as delicately as if actually drawn on the smooth stone. Fragments preserved in ruder fashion abound in the clays and even the sandstones of the earliest geologic ages. In most cases, however, fossil fishes are known from detached and scattered fragments, many of them, especially of the sharks, by the teeth alone. Fishes have occurred in all ages from the Silurian to the present time and no doubt the very first lived long before the Silurian.

No one can say what the earliest fishes were like, nor do we know what was their real relation to the worm-like forms among which men have sought their presumable ancestors, nor to the Tunicates and other chordate forms, not fish-like, but still degenerate relatives of the primeval fish.

From analogy we may suppose that the first fishes which ever were bore some resemblance to the lancelet, for that is a fish-like creature with every structure reduced to the lowest terms. But as the lancelet

has no hard parts, no bones, nor teeth, nor scales, nor fins, no traces of its kind are found among the fossils. If the primitive fish was like it in important respects, all record of this has necessarily vanished from the earth.

The next group of living fishes, the Cyclostomes, including the hagfishes and lampreys,—fishes with small skull and brain but without limbs or jaws,—stands at a great distance above the lancelet in complexity of structure, and equally far from the true fishes in its primitive simplicity. In fact the lamprey is farther from the true fish in structure than a perch is from an eagle. Yet for all that it may be an offshoot from the primitive line of fish-descent. There is not much in the structure of the lamprey which may be preserved in the rocks. But the cartilaginous skull, the backbone, fins and teeth may sometimes leave their traces in soft clay or lithographic stone. These parts are actually represented in a fossil form bearing some likeness to a lamprey found in the Devonian of Scotland known as *Palæospondylus.* This early form was a highly specialized one with well-defined vertebræ, a fact which shows that the group had reached a relatively high development even in these early times. The few existing Cyclostomes may even be looked upon as degraded types as compared with their Devonian ancestors.

Besides the lampreys the Devonian seas swarmed with mysterious creatures covered with a coat of mail, fish-like in some regards, but limbless, without true jaws and having next to nothing in common with the fishes of to-day. These are called Ostracophori, and most recent authorities, as Woodward and Dean, are inclined to regard them as highly modified or specialized lampreys, a side offshoot which has left no descendants among recent forms. Cope has compared these Ostracoderms to the larva of Tunicates, and Patten has suggested their affinity to spiders, or rather to the horseshoe crab (*Limulus*), which is at least as much spider as crab. The weight of evidence would rather place them nearest the lampreys, but certainly not in the same natural class.

Among these forms in coat of mail are some in which the jointed and movable angles of the head suggest the pectoral spines of some catfishes. But in spite of its resemblance to a fin, the spine of the pectoral fin in *Pterichthys* is an outgrowth of the ossified skin and has no more homology with the spines of fishes than the mailed plates have with the bones of a fish's cranium. In none of these fishes has any trace of an internal skeleton been found. It must have retained its primitive gelatinous character. There are, however, some traces of eyes, and the mucous channels of the lateral line indicate that these creatures possessed some other special senses.

Whatever the Ostracophores may be, they are not true fishes and they should not be included within the much-abused term *Ganoidei,*

a word once used in the widest fashion for all sorts of mailed fishes, but little by little restricted to the hard-scaled relatives and ancestors of the gar-pike of to-day.

Dimly seen in the vast darkness of Paleozoic time are the huge figures known as Arthrognaths. These are mailed and helmeted fishes, limbless so far as we know, but with sharp, notched, turtle-like jaws quite different from those of the fish or those of any animal alive to-day. These creatures appear in Silurian rocks and are especially abundant in the fossil beds of Ohio, where Newberry, Claypole, Eastman and Dean have patiently studied the broken fragments of their armor. Most of them have a great casque on the head with a shield at the neck and a movable joint connecting the two. Among them was almost every variation in size and form.

These creatures have been often called ganoids, but with the true ganoids like the gar-pike they have seemingly nothing in common. They are very different from the Ostracophores. To regard them as derived from ancestral Dipnoi is to give a possible guess as to their origin and a very unsatisfactory guess at that. But they have all passed away in competition with the scaly fishes and sharks of later evolution, and it seems certain that they, like the mailed Ostracophores, have left no descendants.

Next after the lampreys, but a long way after in structure as in time, come the sharks. With the sharks appear for the first time true limbs and the lower jaw. The upper jaw is still formed from the palate, and the shoulder girdle is attached behind the skull. "Little is known," says Professor Dean, "of the primitive stem of the sharks and even the lines of descent of the different members of the group can only be generally suggested. The development of recent forms has yielded few results of undoubted value to the phylogenist. It would appear is if paleontology alone could solve the puzzles of their descent."

Of the very earliest sharks in the Upper Silurian age the remains are too scanty to prove much save that there were sharks in abundance and variety. Spines, teeth, fragments of shagreen, show that in some regards these forms were highly specialized. In the Carboniferous age, according to Dean, 'there occurred the culminating point of their differentiation when specialized sharks existed, whose varied structures are paralleled only by those of the existing bony fishes,—sharks fitted to the most special environment, some minute and delicate, others enormous, heavy and sluggish, with stout head and fin spines and elaborate types of dentition.'

The sharks are, however, doubtless evolved from the still more primitive shark without limbs and with the teeth slowly formed from modification of the ordinary shagreen prickles. In determining the earliest among the several primitive types of shark we are stopped by

an undetermined question of theory. What is the origin of paired limbs? Are these formed, like the unpaired fins, from the breaking up of a continuous fold of skin, in accordance with the view of Balfour and others? Or is the primitive limb, as supposed by Gegenbaur, a modification of the bony gill-arch? Or again, as supposed by Kerr, is it a modification of the hard axis of an external gill?

If we adopt the views of Gegenbaur or Kerr, the earliest type of limb is the jointed *archipterygium*, a series of consecutive rounded cartilagenous elements with a fringe of rays along its length. Sharks possessing this form of limb (Ichthyotomi) appear in the earliest rocks, and from these the Dipnoi, on the one hand, may be descended and, on the other, the true sharks and the Chimæras.

On the other hand, if we regard the paired fins as parts of a lateral fold of skin, we find primitive sharks to bear out our conclusions. In *Cladoselache* of the Subcarboniferous, the pectoral and the ventral fins are long and low, and arranged just as they might be if Balfour's theory were true. *Acanthoëssus,* with a spine in each paired fin and no other rays, might be a specialization of this type or fin, and *Climatius* with rows of spines in place of pectorals and ventrals might be held to bear out the same idea. But in all these, the tail is less primitive than in the *Ichthyotomi*. On the whole, however, there is much to be said on the primitive nature of the Ichthyotomi, and *Pleuracanthus,* with the tapering tail and jointed pectoral fin of a dipnoan, with other traits of a shark, is as likely as *Cladoselache* to point directly to the origin of the shark-like forms.

Hasse finds this origin in a hypothetical group of Polyospondyli which have many vertebræ undifferentiated and without calcareous material. These fishes are represented only by fin spines (*Onchus*), which may have belonged to something else. These gave rise to Ichthyotomi, with jointed fins, and through these to Dipnoi and a long series leading to the bony fishes on the one hand and on the other to the Amphibia, Reptiles and Higher Vertebrates.

The branch of higher sharks would lead to the Diplospondyli of Hasse's system, of which *Cladoselache* should be a primitive example. These sharks have the weakly ossified vertebræ joined together in pairs and there are six or seven gill openings. This primitive type called Notidani has persisted to our day, the frilled shark (*Chlamydoselachus*) and the genera *Hexanchus* and *Heptranchias,* still showing its archaic characters.

Here the sharks diverge into two groups, the one with the vertebræ better developed and its calcareous matter arranged star fashion. This forms Hasse's group of Asterospondyli, the typical sharks. The earliest forms (Heterodontidæ, Hybodontidæ) approach the Notidani, and one such ancient type *Heterodontus,* still persists. The others diverge to

form the three chief groups of cat-sharks (*Scyliorhinus,* etc.), mackerel-sharks (*Lamna,* etc.) and iron-sharks (*Carcharhias,* etc.).

In the other group the vertebræ have their calcareous matter arranged in rings, one or more about the notochordal center. In all these the anal fin is absent, and in the process of specialization, is formed the flattened body and broad fins of the ray. This group is called Tectospondyli. Hasse's Cyclospondyli (sharks with one ring of calcareous matter) constitute the most primitive extreme of a group representing continuous evolution.

From *Cladoselache* and *Chlamydoselachus* through the sharks to the rays we have an almost continuous series which reaches its highest development in the devil rays or mantas of the tropical seas, *Manta* and *Mobula* being the most specialized genera and among the very largest of the fishes. However different the rays and skates may appear in form and habit, they are structurally similar to the sharks and have sprung from the main shark stem.

The most ancient offshoot from the shark stem, perhaps dating before Silurian times and having its root in ancient Ichthyotomi, is the group of Holocephali or chimæras, shark-like in essentials, but differing widely in details. Of these there are but few living forms, and the fossil types are known only from dental plates and fin spines. The living forms are found in the deeper seas, the world over, the most primitive genus being the newly discovered *Rhinochimæra.* The fusion of the teeth into overlapping plates, the covering of the gills by a dermal flap, the complete union of the palatoquadrate apparatus or upper jaw with the skull and the development of a peculiar clasping spine on the forehead of the male are characteristic of the chimæras. The group is one of the most ancient, but with the chimæras it ends, for the species has nothing in common with modern fishes except what both have derived from their common ancestors the sharks.

The most important offshoot of the primitive sharks is not the chamæras, nor even the shark series itself, but the group of dipnoans or lung-fishes and the long chain of their descendants. With the dipnoan appears the lung or air-bladder, at first an outgrowth from the ventral side of the oesophagus, as it still is in all higher animals, but later turning over, among fishes, and springing from the dorsal side. At first an arrangement for breathing air, a sort of accessory gill—it becomes the sole organ of respiration in the higher forms, while in the bony fishes its respiratory function is lost altogether. The air-bladder is a degenerate gill. In the dipnoans the shoulder girdle moves forward to the skull, and the pectoral limb, a jointed and fringed archipterygium, apparently derived from ancestors of the type of *Pleuracanthus* is its characteristic appendage. The shark-like structure of the mouth remains.

The few living lung fishes resemble the salamanders almost as closely as they do fishes, and they may well be ranged as a class by themselves midway between the primitive sharks and the amphibians. The few living forms show these intermediate characters in the development of lungs and the primitive character of the pectoral and ventral limbs. Those now extant give but little idea of the great variety of extinct dipnoans, but the obvious suggestion that with the lung fish is the place of divergence of the higher vertebrates from the fish series may be the correct one. The living genera are three in number, *Neoceratodus* in Australian rivers, *Lepidosiren* in the Amazon and *Protopterus* in the Nile. These are all mud fishes, some of them living through most of the dry season encased in a cocoon of dried mud. Of these forms *Neoceratodus* is certainly the nearest to the ancient forms, but its embryology, owing to the shortening of its growth stages due to its environment, has thrown little light on the question of its ancestry.

From some branch of the dipnoans the ancestry of the amphibians and through them that of the reptiles, birds and mammals may be traced, although some reason exists for regarding the primitive *Crossopterygium* as the point of divergence. It may be that the Crossopterygian gave rise to Amphibian and Dipnoan alike.

In the process of development we next reach the characteristic fish mouth in which the upper jaw is formed of maxillary and premaxillary elements distinct from the skull. The upper jaw of the shark is part of the palate, the palate being fused with the quadrate bone which supports the lower jaw. That of the dipnoan is much the same. The development of a typical fish mouth is the next step in evolution and with its appearance we note the decline of the air-bladder in size and function.

The next great offshoot is the group of crossopterygians, fishes which still retain the old-fashioned type of pectoral and ventral fin, the archipterygium. In the archaic tail, enameled scales and cartilaginous skeleton the crossopterygian shows its affinity with its dipnoan ancestry. Thus these fishes unite in themselves traits of the shark, lung-fish and Ganoid. The few living crossopterygians, *Polypterus*, and *Erpetoichthys* are not very different from those which prevailed in Devonian times. The larvæ possess external gills with firm base and fringe-like rays, suggesting a resemblance to the pectoral fin itself which develops from the shoulder-girdle just below it and would seem to give some force to Kerr's contention that the archipterygium is only a modified external gill. In *Polypterus* the archipterygium has become short and fan-shaped, its axis made of two diverging bones with flat cartilage between. From this type it is thought that the arm of the higher forms has been developed. The bony basis may be the humerus,

from which diverge radius and ulna, the carpal bones being formed of the intervening cartilage.

From the crossopterygians springs the main branch of true fishes, known collectively as Actinopteri, those with ordinary rays on the paired fins instead of the jointed archipterygium. The transitional series of primitive Actinopteri is here called by the name of Ganoid. The ganoid differs from the Crossopterygian in having basal elements of the paired fins small and concealed within the flesh. But other associated characters of the Crossopterygii and Dipnoi are preserved in most of the species. Among these are the mailed head and body, the heterocercal tail, the cellular air-bladder, the presence of valves in the arterial bulb, the presence of a spiral valve in the intestine and of a chiasma in the optic nerves. All these characters are found in the earlier types so far as known, and all are more or less completely lost or altered in the teleosts or bony fishes. Among the existing ganoids the gar-pike (*Lepisosteus*) is the last of a long series of Mesozoic forms of the same general structure. The gar-pikes are cylindrical or arrow-shaped. Among these early types is every variety of form, some of them being almost as long as deep, and every intermediate form being represented. An offshoot from this line is the bow-fin (*Amia calva*), perhaps the closest living ally of the bony fishes, showing distinct affinities with the great group to which the herring and salmon belong. Near relatives of the bow-fin flourished in the Mesozoic, among them some with a forked tail, and some with a very long one. From forms of this type the body of recent fishes may be descended.

Another branch of ganoids, widely divergent from both gar-fish and bow-fin and not recently from the same primitive stock, included the sturgeons (*Acipenser, Scaphirhynchus, Kessleria*) and the paddle-fishes (*Polyodon* and *Psephurus*). These differ widely from any other types, recent or fossil, showing features of degeneration as compared with their extinct ancestors, while again sturgeon and paddlefish differ widely from each other. It has been suggested that the cat-fishes (Siluridæ) are descended from the sturgeons, but the resemblance vanishes the more closely the groups are compared, nor are we anywhere sure of the point where any part of the teleost series is joined to the ganoids. We can only say that the sturgeons are more or less degraded ganoids with cartilaginous skeletons, of unknown derivation and of unsettled relationships.

All other fishes have ossified instead of cartilaginous skeletons. The dipnoan and ganoid traits one by one are more or less completely lost. Through these the main line of fish development continues and the various groups are known collectively as bony fishes or teleosts.

The earliest of the true bony fishes or teleosts appear in Mesozoic times, the most primitive forms being soft-rayed fishes with unmodi-

fied vertebræ, allied more or less remotely to the herring of to-day. In these and other soft-rayed fishes the pelvis still retains its posterior insertion, the ventral fins being said to be abdominal. The next great stage in evolution brings the pelvis forward, attaching it to the shoulder girdle so that the ventral fins are now thoracic as in the perch and bass. If brought to a point in front of the pectoral fins, a feature of specialized degradation, they become jugular as in the cod-fish. In the abdominal fishes the air bladder still retains its rudimentary duct joining it to the oesophagus.

From the abdominal forms allied to the herring, the huge array of modern fishes, typified by the perch, the bass, the mackerel, the wrasse, the globe-fish, the sculpin, the seahorse and the cod descended in many diverging lines. The earliest of the spine-rayed fishes with thoracic fins belong to the type of Berycidæ, a group characterized by rough scales and the retention of the primitive larger number of ventral rays. These appear in the Cretaceous or chalk deposits, and show various attributes of transition from the abdominal to the thoracic type of ventrals.

Another line of descent apparently distinct from that of the herring and salmon extends through the characins to the loach, carps, cat-fishes and electric eel. The fishes of this series have the anterior vertebræ coossified and modified in connection with the hearing organ, a structure not appearing elsewhere among fishes. This group includes the majority of fresh-water fishes. Still another great group, the eels, have lost the ventral fins and the bones of the head have suffered much degradation.

The most highly developed fishes, all things considered, are doubtless the allies of the perch, bass and sculpin. These fishes have lost the air-duct and on the whole they show the greatest development of the greatest number of structures. But they do not represent an excessive degree of specialization. In other groups their traits one after another are carried to an extreme and these stages of extreme specialization give way one after another to phases of degeneration. The specialization of one organ usually involves degeneration of some other. Extreme specialization of any organ tends to render it useless under other conditions and may be one step toward its final degradation.

We have thus seen, in hasty review, that the fish-like vertebrates spring from an unknown and possibly worm-like stock,—that from this stock, before it became vertebrate, degenerate branches have fallen off, represented to-day by the *Tunicates* and *Balanoglossus*. We have seen that the primitive vertebrate was headless and limbless without hard parts. The lancelet remains as a possible direct off-shoot from it; the cyclostome with brain and skull is a probable derivative from archaic lancelets. The earliest fishes leaving traces in the rocks were doubtless cyclostomes, limbless, naked lampreys and mailed ostracophores. The

lampreys gave rise to sharks and chimæras. The sharks developed into rays in one right line, and into the highest sharks along another; while by a side branch through lost stages the primitive sharks passed into dipnoans or lung-fishes. All these types and others abound in the Devonian age and the early records were lost in the Silurian. From the lung-fishes or the ancestors or descendants by the specialization of the lung and limbs, the land animals, at first amphibians, after these reptiles, birds and mammals, arose.

In the sea, by a line still more direct, through the gradual emphasis of fish-like characters, we find developed the crossopterygians with archaic limbs and after these the ganoids with fish-like limbs but otherwise archaic; then the soft-rayed and finally the spiny-rayed bony fishes which culminate in specialized and often degraded types, as the anglers, globe-fishes, parrot-fishes and flying gurnards. Side branches are the ostracophores, perhaps from primitive lampreys; arthrognaths from a lost ancestry possibly; chimæras, from primitive sharks, and rays from sharks less primitive; dipnoan sturgeons, gar-pikes and perhaps carp and cat-fishes; and from each of the ultimate lines of descent radiate infinite branches till the sea and rivers are filled, and almost every body of water has fishes fitted to its environment.

SCIENTIFIC LITERATURE.

BIOGRAPHIES OF EMINENT CHEMISTS.

THE literature of chemistry has recently been enriched by several biographies of chemists and by carefully edited works reproducing the letters that passed between certain chemists; the importance and value of these volumes is enhanced by the reflection that the history of the lives of the leading men in a growing science constitutes the most complete history of the science in that period during which they labored, and their lives and labors are reflected in their letters. These notions are appreciated by most of the editors of the correspondence we have in mind, and they make their tasks of double value by introducing numerous bibliographic and explanatory notes.

No student of the progress of chemistry in France during the second quarter of the century just closed can acquire a full and correct knowledge of the subject without a perusal of the life of Charles Gerhardt, edited by his son (bearing the same name), and by Edouard Grimaux (Paris, 1900). In his short life of only forty years, Gerhardt introduced ideas into chemistry that were at first thought to be revolutionary, but were eventually adopted even by his adversaries; his services to organic chemistry were of the highest importance; he first doubled the atomic weights of carbon, oxygen and sulfur, divided acids according to their basicity, and completely established the individuality of the equivalent, the atom and the molecule.

Of a very different type was his contemporary living across the Rhine, Schönbein, whose life has been sympathetically written by his successor in the University chair, Dr. Geo. W. A. Kahlbaum (Leipzig, 1899–1901, 2 vols.). The painstaking, indefatigable discoverer of ozone, of gun-cotton, of collodion, and of the passive state of iron, forms a strong contrast to the brilliant, keen-sighted investigator in organic chemistry, Gerhardt. Schönbein's busy yet uneventful life reaped but a paltry reward for a discovery that subsequently brought the Swedish manufacturer a colossal fortune; but none knew better than Schönbein that the reward sought by the investigator in the chemical laboratory is success in wresting from nature her hidden truths.

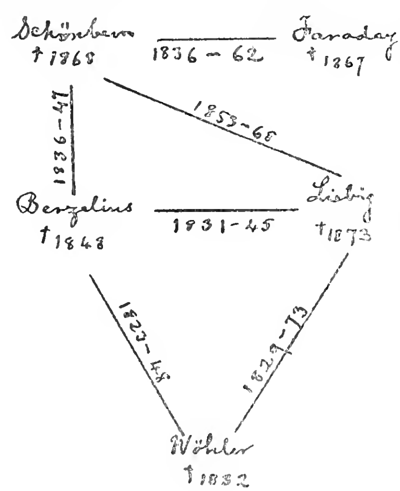
Schönbein was a voluminous writer of letters; Dr. Kahlbaum made a collection of over 1,600, besides 350 printed papers, and analyzed them carefully in compiling the volumes named. One of his most regular and valued correspondents was Faraday, and the letters interchanged with him have been published in another volume edited by Dr. Kahlbaum and Francis V. Darbishire (Bâsle and London, 1899). These letters number 155 and cover the period from 1836 to 1862, beginning with a letter from Schönbein announcing the peculiar behavior of iron in nitric acid of a certain strength, and ending with a brief note from Faraday that painfully discloses his mental distress. The first mention of a 'phosphorus smell developed by electricity' occurs in a letter to Faraday dated April 4, 1840, and the exciting cause of this odor occupies some part of nearly every letter to Faraday during the succeeding twenty-two years.

Dr. Kahlbaum, with others, has published 'Twenty Letters,' exchanged by Schönbein and Berzelius in the years 1836 to 1847 (Bâsle, 1898), and the

same in an English dress (London, 1900), also the 'Letters of Schönbein and Liebig, 1853–1869' (Leipzig, 1898), so that the correspondence of Schönbein is largely accessible to students seeking details.

These several volumes of correspondence suggest others that are analogous. The 'Letters of Berzelius and Liebig, 1831 to 1845,' edited by Justus Carrière with the cooperation of the Bavarian Academy of Sciences (Munich, 1893), and the correspondence between Berzelius and Wöhler, published by the Royal Academy of Göttingen, and edited by O. Wallach (Leipzig, 1901, 2 vols.).

And to complete this series of letters that passed between eminent chemists there remains the 'Correspondence of Liebig and Wöhler,' edited by A. W. von Hofmann, and Emilie Wöhler (Braunschweig, 1888, 2 vols). These cover the long period from 1829 to 1883. The inter-relations of these six works with the dates of the correspondence and of the death of each chemist, may be graphically shown by a diagram.



The perusal of letters between intimate friends having mutual interests in kindred studies is much like listening to conversation carried on between them; they reveal their daily life, domestic happiness and difficulties, their likes and dislikes, their humor and their satire, their successes and failures in research, and their ambitions and discouragements. They also disclose their weaknesses and perhaps their foibles, and they unconsciously divulge the greatness of their intellects, all in simple language, not written to produce startling effects nor to exaggerate their own importance in the minds of readers.

All these volumes are illustrated by one or more portraits, and some of them contain facsimiles of manuscripts.

MOSQUITOES.

A Monograph of the 'Culicidæ or Mosquitoes of the World' has just been prepared by Mr. Fred. V. Theobald, and is published by the British Museum as one of its regular series. There are two volumes of text aggregating 835 pages and one volume of plates, numbering 37 and containing 148 colored figures of adults. Then there are 5 plates, each containing six solar prints of microphotographs illustrating wing scales. In the text are 318 woodcuts, half-tones or similar figures. In these books 258 species of mosquitoes, divided among 22 genera, are described, and 37 species in 10 genera are credited to North America. Although the work is just off the press it is already out of date, and in the introductory remarks by the director of the museum, dated November, 1901, a supplementary volume is promised. All these facts indicate the remarkable interest that has been of late universally aroused in the subject, and the enormous collections that have been and are now being made in all parts of the world. In the United States several new species were recognized and described in 1901, two of them from New Jersey. The life history of several species has been made out, and good structural characters for their separation appear as the result of American study. Mr. Theobald describes 136 new species; almost as many as were described in all previous

times, and he indicates the possession of something like 50 additional forms.

Almost 100 pages are devoted to the peculiarities of mosquitoes in all stages, and to the methods to be employed in studying them. The mouth structures are explained in the conventional way and the matter of food is gone into somewhat in detail. Of course comparatively few mosquitoes ever get a meal of blood, and yet it would seem that for some species such a meal is an essential preliminary to reproduction. All sorts of vertebrates may be attacked, even fish and reptilia, and invertebrates seem almost as susceptible. The males, being unable to puncture either animal or vegetable tissue, are confined to a diet of prepared liquids—nectar and the like—but do not despise others, like beer and wine, when they can get them.

To mosquitoes as disease carriers only a few pages are devoted; the author referring to such writings as Ross's, Grassi's, Nuttall's and others. He specifically discusses 'Malaria,' filariasis and yellow fever, though adding nothing from personal observation. Birds and probably some animals suffer from diseases carried by these insects and usually only one, or a small group of species, acts in the transmission. Thus the species of *Anopheles*, in America at least, is responsible for the distribution of *malarial* troubles, while *Stegomyia* appears to do as much for yellow fever.

Mr. Theobald emphasizes the character of the scales on certain portions of the head, wing and body, which assists in separating species. This brings into play the microscope and, practically, that instrument must be resorted to for final determinations in some instances.

It is altogether a very interesting and useful book to the entomologist who wishes to learn what has been done in this family and who has done it. The plates are too highly colored and the figures are, therefore, misleading. The text figures, illustrating structural details, are as a whole only fair, though the point to be illustrated is always well brought out. The book-maker's work is well done, and so is the printer's, while a good index adds materially to the facility with which the book may be used by the reader.

MECHANICS.

An 'Elementary Treatise on Theoretical Mechanics' by Professor W. Woolsey Johnson (Wiley and Sons, New York) is far from elementary, as the reader is supposed to have a good knowledge of differential and integral calculus. The laws of nature are, however, quite independent of any system of mathematics, and many of those discussed in this volume might be easily treated by elementary algebra and geometry. There can be no objection to the use of the calculus if its demonstrations are simpler than those of common methods, but the combination of difficult mathematics with difficult subject-matter should be avoided in an elementary text-book. The plan of the book is that usual in this subject, forces being discussed at much length, in connection with the time-rate of space or velocity, before the subject of work or energy is taken up. This plan follows the historical line of development, but it is questionable whether it is the best method for the student or for getting at practical solutions. The book contains no unsound doctrine, is concisely written in a scholarly tone, and is an able presentation of the subject under the plan adopted.

THE PROGRESS OF SCIENCE.

THE JOHNS HOPKINS UNIVERSITY.

On February 21 and 22 the Johns Hopkins University celebrated the twenty-fifth anniversary of its founding and the installation of its second president. In Europe, where the life of a university is measured by centuries, it may be looked on as a sign of crudeness for us to celebrate the tenth or the twenty-fifth anniversary of the establishment of a university. It is, however, a notable fact that universities such as the Johns Hopkins or Chicago should have surpassed so quickly most of the great European institutions not only in size and wealth, but also in their real contributions to higher education and the advancement of knowledge. The Johns Hopkins University will always occupy an important place in the history of the American university. The opportunity given by an endowment unhampered by restrictions or precedents was fully grasped by President Gilman. He called together a small group of professors — Sylvester, Rowland, Remsen and Martin in the sciences—unequaled as leaders in research. By the establishment of a system of fellowships, a group of students was gathered together who have since represented the most advanced work of the country. In the erection of cheap buildings equipped with expensive apparatus, in the creation of working seminar libraries in place of a museum of books, in the establishment of scientific journals and in other ways, the university set an excellent example. But its chief claim to our honor is the supreme place it gave to advanced work and investigation by both teachers and students. In the recent establishment of a medical school the same methods have been followed, and the university has again led in a great forward movement.

On the first day of the exercises at Baltimore, Dr. D. C. Gilman, who guided the university during its twenty-five years and has now undertaken an equally important office in the presidency of the Carnegie Institution, gave a commemoration address. On the second day, Dr. Ira Remsen, who has been professor of chemistry since the opening of the university, was formally installed as president, and gave the inaugural address. Both addresses were of great interest not only to those who have been connected with the university, but also to all who are interested in higher education. The addresses will be found in the issue of *Science* for February 28, and will doubtless be published by the University. In addition to these two addresses, there was a reception, a luncheon at the hospital, a dinner by the alumni and other events. Degrees were conferred on a number of university presidents and others. Of the six to whom the doctorate of laws was awarded, on the ground of their association in carrying on the work of the university, five are men of science—Dr. J. S. Billings, Dr. G. Stanley Hall, Professor J. W. Mallet, Dr. C. D. Walcott and Professor Simon Newcomb. The same degree was given to four alumni, including Professor Josiah Royce and Professor E. B. Wilson.

THE NATIONAL MUSEUM.

It is to be hoped that the urgent recommendation for the enlargement of the U. S. National Museum made to congress by Secretary Langley will receive consideration. The present building is truly a scandal. Specimens of

great value are exhibited—most of them are as a matter of fact stored out of view—in inflammable sheds. The secretary makes a comparison with the American Museum of Natural History in New York City, which shows that while the number of specimens in the National Museum is more than double the number in the American Museum, the space of the American Museum is ten times as great as that of the National Museum, and the cost of the buildings was also ten times as great. If New York City spends $4,000,000 on its museum buildings, it seems strange that the general government can not do at least as much. Our national government has been extremely liberal in its appropriation for scientific purposes, surpassing in this respect other governments, but for some reason—probably by mere accident—the museum has been neglected. Washington is becoming a scientific center, rivaling London, Paris and Berlin, but compared with the museums maintained in these cities by the government our national museum is not creditable. The collections though large are not systematic, having resulted from expeditions, gifts and the like, while no appropriations have been available to fill in the gaps which always arise when collections are formed by such methods. The curators do not receive adequate salaries; indeed, of the twenty-one curators, twelve serve without any salary at all, and the average salary of the others is only about $2,500. The keepers of the British Museum of Natural History receive salaries of $4,000. It should be only necessary to point out these matters to congress in order that appropriations may be made for the National Museum commensurate with those of foreign governments. The difficulty is that there are no members of congress who are scientific men, or who are primarily interested in science, such as are to be found in all foreign legislatures, and there is consequently no one who will present to congress the consensus of opinion of scientific men.

A NEW BRITISH ACADEMY.

National Academies had more important functions in the past than they have now. Still the honor of being officially recognized as one of a small body of eminent men may be a stimulus to scientific work, and academies may be among the best existing means of forwarding international relations. Neither in the United States nor in Great Britain has an academy of letters arisen. It seems, however, that a British Academy for the promotion of historical, philological and philosophical studies will soon be established by royal charter. The question of such an academy has been discussed in England since the organization in 1899 of the International Association of Academies. Literary as well as scientific academies are part of this association, and Great Britain can only be represented by the Royal Society. The International Association will hold its next meeting in London in 1904, and the lack of representation of historical and literary studies would thus be emphasized. The question arose as to whether the Royal Society might be enlarged to include students of history, economics, philology, etc., as was apparently intended by the original charter of King Charles II. Many members of the Society favored the plan, but it was rejected by the council. It is probable that the leading English students of the humanities from the scientific side will be permitted to organize themselves into an academy, and that there will hereafter be in Great Britain a new Royal Academy as well as a Royal Society. The National Academy of Sciences was intended to include students of economics, philology and similar sciences, but the few representatives of these sciences have died and no successors have been elected. It seems likely that, unless the National Academy decides to give

recognition to sciences other than those commonly called natural and exact, the conditions that prompted the establishment in England of a special Academy may lead to a similar undertaking in the United States. The national societies devoted to history, economics, philology, archeology and the like fill most of the important functions that were formerly exercised by a national academy, but there appears to be as much reason for the students of these sciences to unite in a national academy as there is in the case of the natural sciences. There seems also reason to suppose that the societies referred to will form some basis of cooperation as the natural sciences have done by uniting in the American Association. Whether all the sciences should unite in one national academy and in one national association or whether they should divide into two separate groups is certainly a question of considerable importance.

THE GERMICIDAL ACTION OF THE ORGANIC PEROXIDES.

Drs. F. G. Novy and P. C. Freer, of the University of Michigan, presented at the Chicago meeting of the American Society of Bacteriologists an important paper that has been extensively, but not very accurately, reported in the daily papers. The authors stated that their investigation was begun with the object of finding the correct explanation of the action of metals and of sunlight upon bacteria. Certain metals, such as gold and copper, exert a marked inhibiting and even germicidal effect upon some bacteria, but the interpretation of the results has not been wholly satisfactory. The fact that various surfaces, such as metals and fabrics, exert a marked effect upon the formation of benzoyl acetyl peroxide was established by the authors and served as a basis for the view that metals act upon bacteria by giving rise to energetic peroxides, which, of necessity, must be more active than ordinary peroxides. The action of sunlight has been ascribed by different workers to hydrogen peroxide, but the destructive action observed is greater than that which can be credited to this body. In order to substantiate the theory of the authors regarding the action of metals and of sunlight, it was deemed necessary to investigate the action of a number of known organic peroxides. The results show that some of these bodies, such as aceton peroxide and dibenzoyl peroxide, are wholly inert. On the other hand, solutions of diacetyl, benzoyl acetyl, and of benzoyl hydrogen peroxides, and of phthalmonoperacid, exert pronounced and even remarkable germicidal properties. With reference to diacetyl peroxides and benzoyl acetyl peroxide, it was shown that the bodies themselves are chemically and bacterially inert, but on contact with water they undergo hydrolysis and give rise to the extremely energetic acetyl hydrogen and benzoyl hydrogen peroxides. A solution of these peroxides (1: 3,000) is capable of destroying all pathogenic bacteria. Cholera and typhoid germs added to tap water are promptly destroyed by the addition of one part of peroxide to 100,000 parts of water. The authors point out the probable value of these peroxides in the prevention and cure of these and allied diseases. The destruction of bacteria in the mouth and saliva takes place with extraordinary rapidity and the reagents have shown themselves useful in diseases of the mouth. The powerful effects of the organic peroxides is not explainable as due to nascent oxygen, since a solution of hydrogen peroxide, which will produce equal germicidal action, contains one or even two hundred times as much nascent oxygen. The authors incline to the belief that the acetyl and benzoyl ions are the active agents.

TWILIGHT IN THE TROPICS.

Professor S. I. Bailey, of the Harvard College Observatory, presented a

paper at the Washington meeting of the Astronomical and Astrophysical Society of America, in which he said that if there were no atmosphere, there would be no twilight, and the brightness of midday would be succeeded, the moment after sunset, by the darkness of midnight. Twilight may be said to last until the last bit of illuminated sky disappears from the western horizon. In general it has been found that this occurs when the sun has sunk about 18° below the horizon. The duration of time which the sun takes in reaching this position is very different at different latitudes. At the North Pole one would have about six months of daylight, followed by nearly two months of decreasing twilight, followed in turn by more than two months of night. In summer, at latitudes greater than 50°, twilight lasts from sunset to sunrise. There is no night there during this season. In the temperate zones the duration of twilight ranges from an hour and a half to more than two hours. Within the tropics the sun descends nearly or quite vertically; but even here the time required for the sun to reach a point 18° below the horizon is more than an hour. There seems to be no reason, therefore, in the general theory, for the widespread belief that the duration of the tropical twilight is extremely brief. This idea is found not only in current popular literature, but also in some of the best text-books on general astronomy. Young's 'General Astronomy,' says: "At Quito and Lima it (the twilight) is said to last not more than twenty minutes." 'The Heavens Above,' by Gilbert and Rolfe, remarks: "Within the tropics, where the air is pure and dry, twilight sometimes lasts only fifteen minutes." Since Arequipa, Peru, lies within the tropics and has an elevation of 8,000 feet, and the air is especially pure and dry, the conditions appear to be exceptionally favorable for an extremely short twilight. On Sunday, June 25, 1899, the following observations were made at the Harvard Astronomical Station, which is situated there: The sun disappeared at 5:30 P.M., local mean time. At 6:00 P.M., 30 m. after sunset, I could read ordinary print with perfect ease. At 6:30 P.M. I could see the time readily by an ordinary watch. At 6:40 P.M., 70 m. after sunset, the illuminated western sky was still bright enough to cast a faint shadow of an opaque body on a white surface. At 6:50 P.M. the illumination was faint, and at 6:55 P.M., 1 h. and 25 m. after sunset, it had disappeared. On August 27, 1899, the following observations were made at Vincocaya. The latitude of this place is about 16° south, and the altitude 14,360 feet. Here it was possible to read coarse print 47 m. after sunset, and twilight could be seen for an hour and twelve minutes after the sun's disappearance. It appears, therefore, that while the tropical twilight is somewhat shorter than occurs elsewhere, and is still further lessened by favorable conditions, such as great altitude and a specially pure air, it is never less, and generally much longer, than an hour.

A GENUS OF GREAT ANTIQUITY.

THE number of genera which came into existence in early geological times and have persisted until the present day is very small, and a study of the recent representatives of such genera is always of interest. The gasteropod genus, Pleurotomaria, made its appearance during the lower Cambrian period and is represented in the seas of to-day by at least four species, *P. Quoyana*, *P. Adansoniana*, *P. Beyrichii* and *P. Rumphii*. These species were founded on the characters of the shells alone, and the animal remained unknown until 1871, when Professor Louis Agassiz dredged a specimen of *P. Quoyana* off the Barbadoes in about 100 fathoms. Additional specimens of both *Quoyana* and *Adansoniana* were obtained by the 'Blake' under the direction of

Mr. Alexander Agassiz in 1879 and have been described by Dr. Dall and by MM. Bouvier and Fischer. More recently several specimens of *P. Beyrichii* have been taken off the coast of Japan from a depth of 70 to 80 fathoms and have formed the basis of a description by Mr. Martin F. Woodward, which appears in a recent number of the 'Quarterly Journal of Microscopical Science' (March, 1901).

As might be expected from its great antiquity, Pleurotomaria presents a number of primitive characteristics which throw considerable light upon the affinities of the different groups of the Mollusca. Possessing two gills, two kidneys and two auricles to the heart, it belongs to the suborder termed Diotocardia zygobranchia, a group which also includes the genera Haliotis and Fissurella; and which, on account of the approximation of its members to a greater degree of bilateral symmetry than is found in the majority of the Gasteropods, is generally regarded as being the most primitive group of its order. In several respects, however, Pleurotomaria is found to possess structural characters of a more primitive nature than those found in other diotocardiates and appears to stand in closer relation to the main line from which the monotocardia have diverged than any other recent genus.

It would require more space than can be allowed here to mention all the important results obtained by Mr. Woodward, but attention may be called (1) to the primitive condition of the nervous system, whose cells are scattered along the various connectives and are not aggregated into definite ganglia—a condition recalling that obtaining in the Amphineurous Mollusca; and (2) to the peculiar position of the supporting skeleton of the gills, which, taken into consideration with the occurrence of a well-developed spinal cæcum attached to the stomach, suggests to Mr. Woodward's mind a comparison and possibly an affinity with the Cephalopods, in which similar conditions exist.

SCIENTIFIC ITEMS.

The students of the University of California held memorial exercises in honor of the late Professor Joseph Le Conte on February 26, the anniversary of his birth. Funds are being collected to assist in the erection of a granite lodge which the Sierra Club proposes to construct in the Yosemite Valley as a memorial to Dr. Le Conte.—Plans have been formed for the erection of a memorial tower and meteorological station in honor of Dr. J. P. Joule, F.R.S., at Sale, Cheshire, where he lived from 1872 to the time of his death in 1880.

Professors William James and W. Wundt, the eminent psychologists, and Professor James Dewar, the eminent chemist, have been elected honorary members of the New York Academy of Sciences.—Professor Hermon C. Bumpus has been appointed director of the American Museum of Natural History, New York.—Professor W. H. Brewer, for thirty-seven years professor of agriculture in the Sheffield Scientific School of Yale University, will retire from the active duties of the professorship at the end of the present academic year.

It will be remembered that Mr. J. Pierpont Morgan gave last year $1,000,000 for the rebuilding of the Harvard Medical School. An equal sum has recently been given by Mr. John D. Rockefeller, and nearly the same amount has been given by others, including $250,000 from Mrs. C. P. Huntingdon and $100,000 from Mr. James Stillman.

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THE NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS.